A PROCEDURE FOR THE CHARACTERISATION OF CORRECTOR MAGNETS

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INTRODUCTION

Two straights in the Diamond Storage Ring (I13 and I09) were modified with vertical mini-beta and horizontally focusing optics, resulting in the need for two extra correctors in the modified straights for each plane. The additional correctors are different in design to standard correctors used around the rest of the Storage Ring. Moreover these mini-beta correctors are not identical as the size of the vacuum chamber over which they fit are different.

A common way of modelling a system is to find the frequency response, or response to a sinusoid. Such a method to measure the dynamic response of the Storage Ring correctors was developed so that the dynamics of the mini-beta correctors can be measured and compared to the standard corrector magnets and the impact on the fast orbit feedback (FOFB) performance can be determined.

1. MEASUREMENT PROCEDURE

- ❑ Excite a single corrector with sinusoidal signal:
  - ➢ $u(t) = u_0 \sin(\omega t)$ for time t_{start} to t_{end}
- ❑ Collect BPM data from time t_{start} to t_{end} which is also a sinusoid:
  - ➢ $y(t) = y_0 \sin(\omega t + \phi)$
- ❑ Extract IQ data from $y(t)$
- ❑ Calculate the amplitude and phase of IQ data:
  - ➢ $y_0 = \sqrt{(I^2 + Q^2)}$
  - ➢ $\phi = \arctan(Q/I)$
- ❑ Repeat measurements for all required excitation frequencies
- ❑ For each excitation frequency, the gain and phase of the system is determined by:
  - ➢ Gain $K = y_0/u_0$ and Phase $= \phi$
- ❑ Repeat measurements for all required correctors

Key experiment parameters:

- ❑ Excitation frequencies
  - ➢ chosen where dynamic behaviour is expected
- ❑ Duration of each excitation
  - ➢ chosen with sufficient cycles
- ❑ Sample frequency
  - ➢ chosen so that Nyquist frequency is much larger than dynamic range of system
- ❑ Amplitude of excitation signal
  - ➢ chosen to obtain optimal signal to noise performance and avoid saturation and rate limits

3. CLOSED LOOP CHARACTERISATION

To characterise the closed loop sensitivity

- ❑ Follow frequency response measurement procedure (with FOFB on)
- ❑ Determine for each excitation frequency:
  - ➢ Closed Loop Gain (K_{closed})
  - ➢ Closed Loop Phase (ϕ_{closed})
- ❑ Determine for each excitation frequency:
  - ➢ Sensitivity Gain $= K_{\text{closed}}/K_{\text{open}}$
  - ➢ Sensitivity Phase $= \phi_{\text{closed}} - \phi_{\text{open}}$

The theoretical sensitivity for the standard corrector predicts that at 10Hz, the closed loop provides around 20dB attenuation of disturbances but at the cost of amplifying disturbances above 150Hz by a maximum of 3dB at 400Hz.
The data shows that there is no significant difference in sensitivity measurements at low frequencies, which is expected because the frequency response of the corrector magnets do not differ below 500Hz in each plane. This means that while one set of magnets has a larger bandwidth, there is no FOFB performance deterioration.

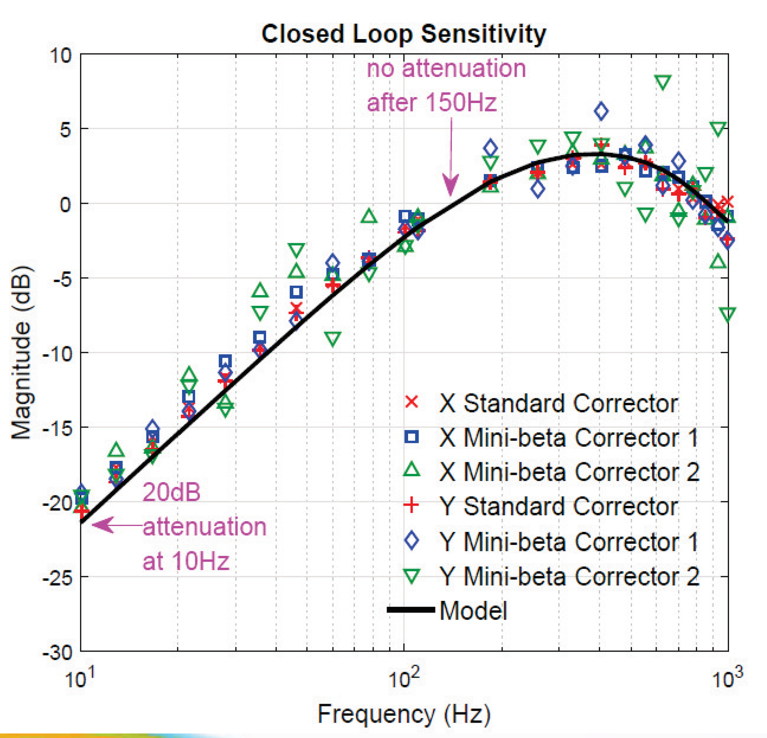

Fig3. The magnitude of the sensitivity function for each magnet in both planes is shown. The standard and mini-beta correctors provide similar levels of attenuation indicating that FOFB performance is not affected by the difference in bandwidths.

2. OPEN LOOP CHARACTERISATION

To characterise the open loop system:

- ❑ Follow frequency response measurement procedure (with FOFB off)
- ❑ Determine for each excitation frequency:
  - ➢ Open Loop Gain (K_{open})
  - ➢ Open Loop Phase (ϕ_{open})

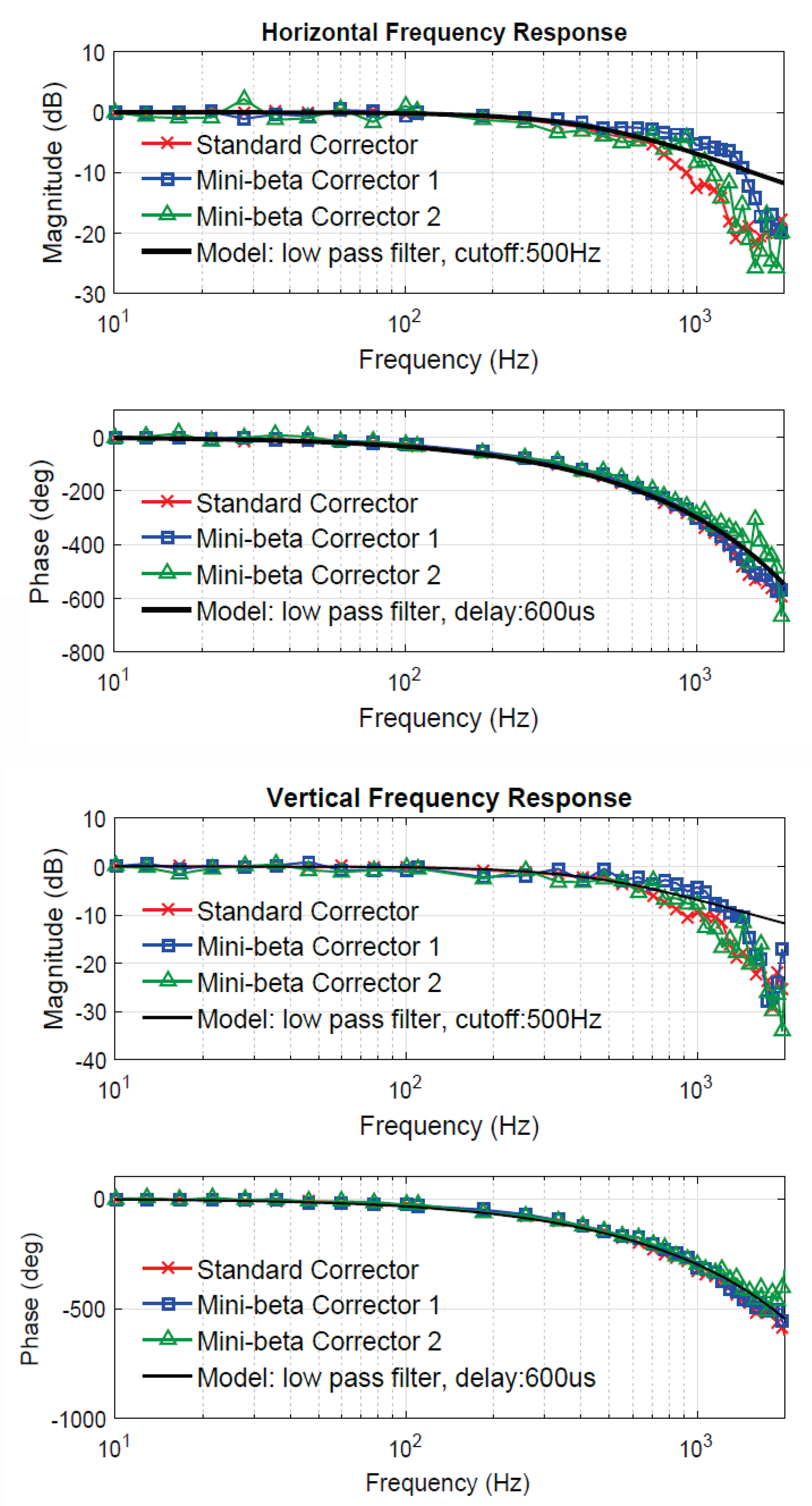

Fig1. The gain and phase response for each magnet is shown for each excitation frequency. From this plot, the open loop parameters are determined. The standard corrector and mini-beta corrector 2 responses are both modelled as a first order low pass filter with bandwidth of 500Hz while the mini-beta corrector 1 has a bandwidth of 700Hz. The presence of a delay component is detected from the phase information and is extracted in Fig2.

Open Loop Characterisation Procedure:

- ❑ Determine the approximate order of the model
  - ➢ by measuring the high frequency roll-off
- ❑ Determine the open loop bandwidth
  - ➢ by measuring the frequency at which the gain (in dB) drops by 3dB
- ❑ Determine the open loop delay
  - ➢ by extracting the delay only information from the phase information

The measured system, which includes dynamics contributed by the magnet power supplies, the magnet itself, the vacuum vessel and external disturbances, can be modelled by a ***first order low pass filter plus a delay**. **For the FOFB design a model with bandwidth of 500Hz and delay 600μs was used.***

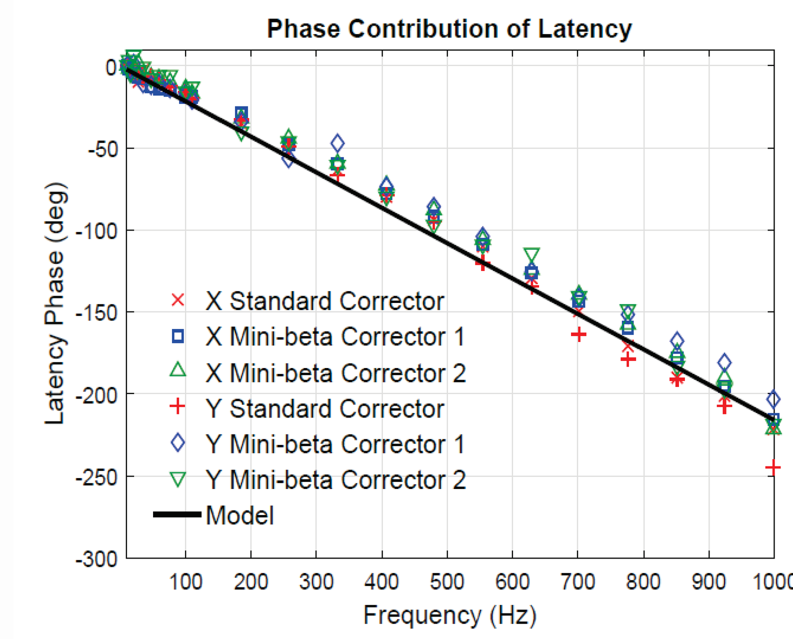

Fig2. Phase contributed by the delay component of the system in horizontal and vertical planes for each magnet is shown compared with a linear fit. The phase contribution of the delay is determined by taking the difference between the measured phase and expected phase for a first order model. A delay of 600μs is a best fit for all magnets.

4. CONCLUSIONS

The characterisation method presented here has the following advantages:

- ❑ The response can be measured directly and gives the frequency response immediately.
- ❑ The experiment parameters such as the relevant dynamic frequencies, the duration of each excitation, the sample frequency and the type of input signal can be easily modified by the user.
- ❑ The input and output signals are only analysed at specific frequencies, so the amount of data is reduced significantly from the number of time domain samples to the number of considered frequencies.
- ❑ No significant processing is required to obtain a Bode plot which can then be used to derive a simple model of the open loop used to synthesise an appropriate controller.

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