AC COUPLING STUDIES AND CIRCUIT MODEL FOR LOSS MONITOR RING

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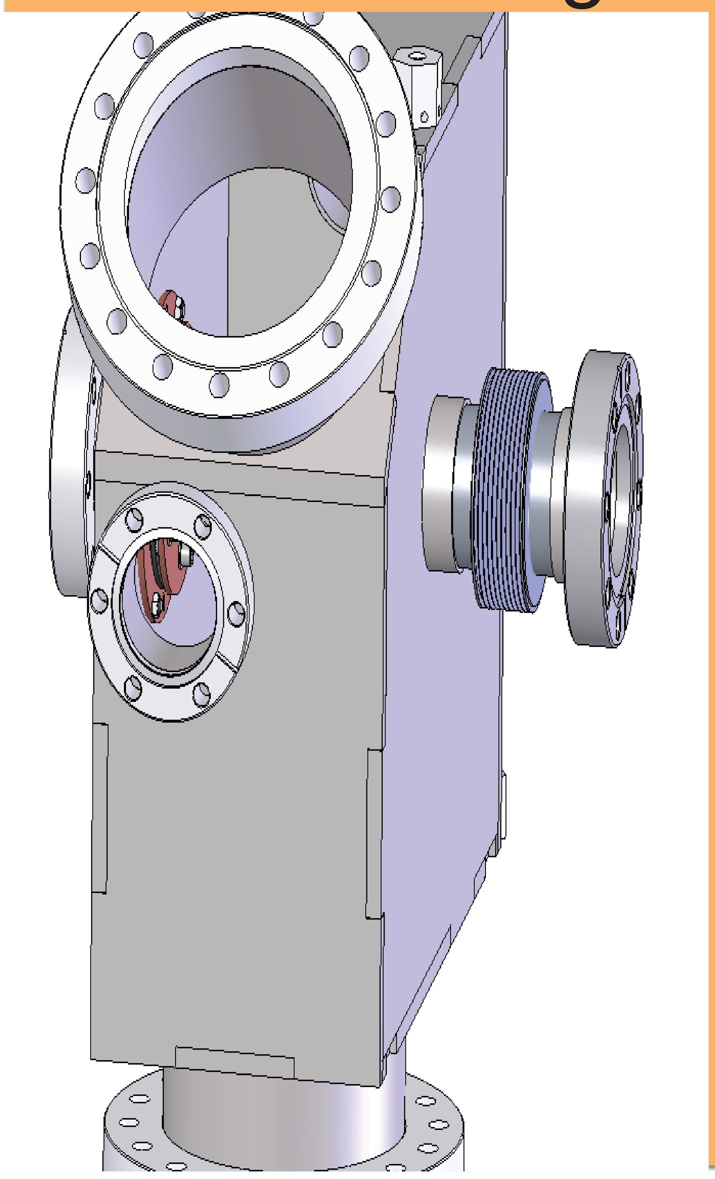
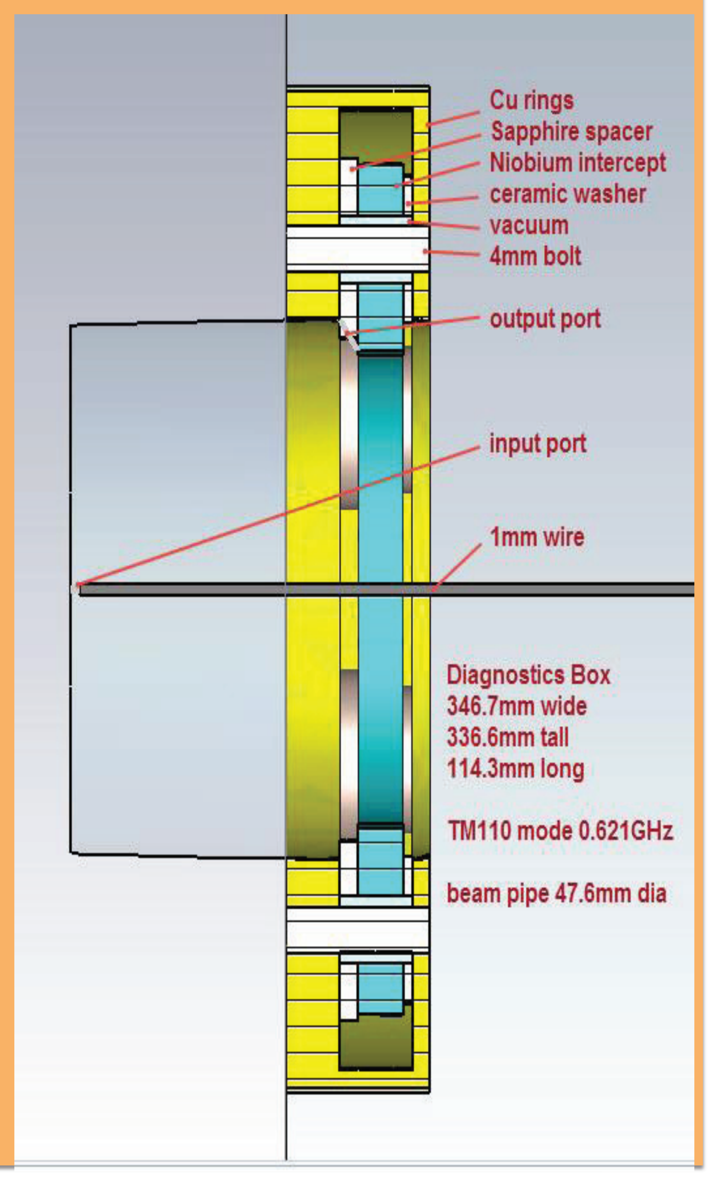
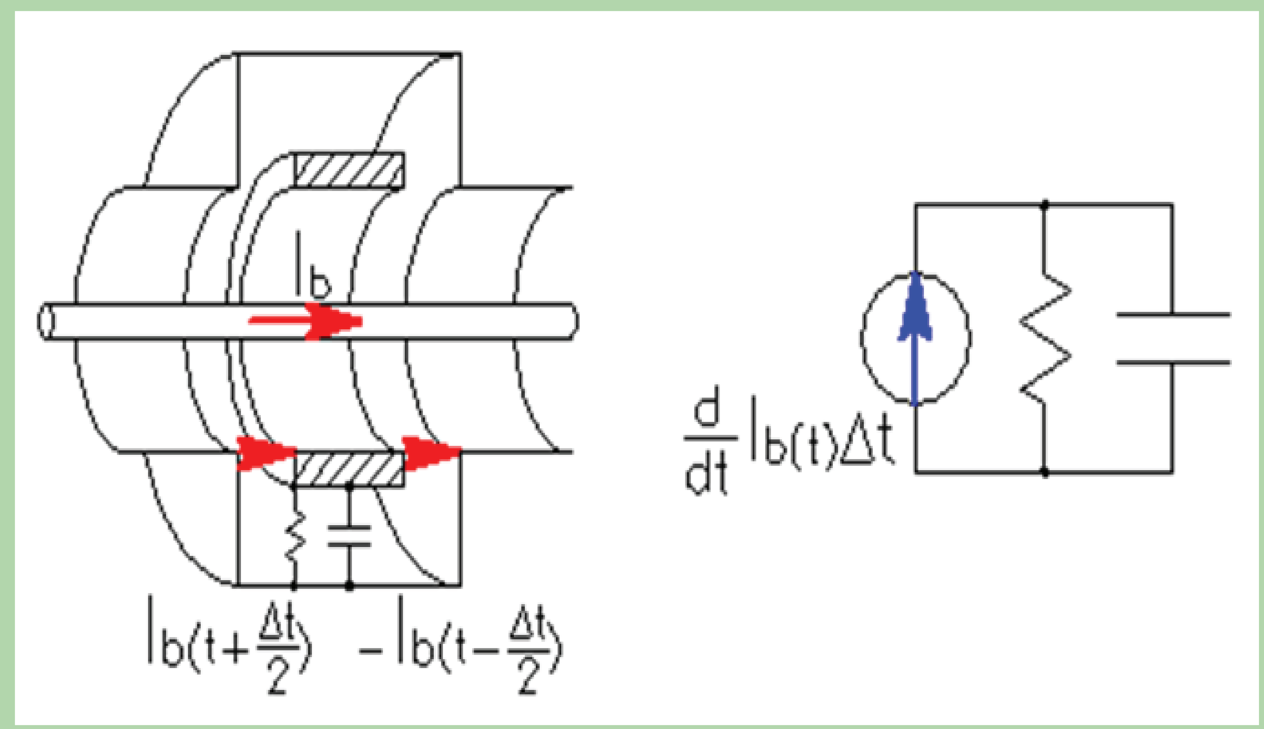
As a follow-up study to the initial design of FRIB Loss Monitor Ring (previously named Halo Monitor Ring), we present recent results of coupling studies between the FRIB CW beam and the Loss Monitor Ring (LMR). While we proposed a ~33 kHz low-pass filter to attenuate high-frequency AC-coupled signals, the LMR current signal may still contain some AC-coupled signals induced by the un-intercepted beam, especially by the 50μs beam notch. We use CST Microwave Studio to simulate the AC response of a Gaussian source signal and benchmarked it to analytical model. A circuit model for beam-notch-induced AC signal is deduced and it should put ~33pA (peak) bipolar pulse on the LMR at 100Hz repetition rate. Although its amplitude falls into our tolerable region, we could consider background integration for an extended time to eliminate this effect.

LMR Design and CST Model





Analytical Model



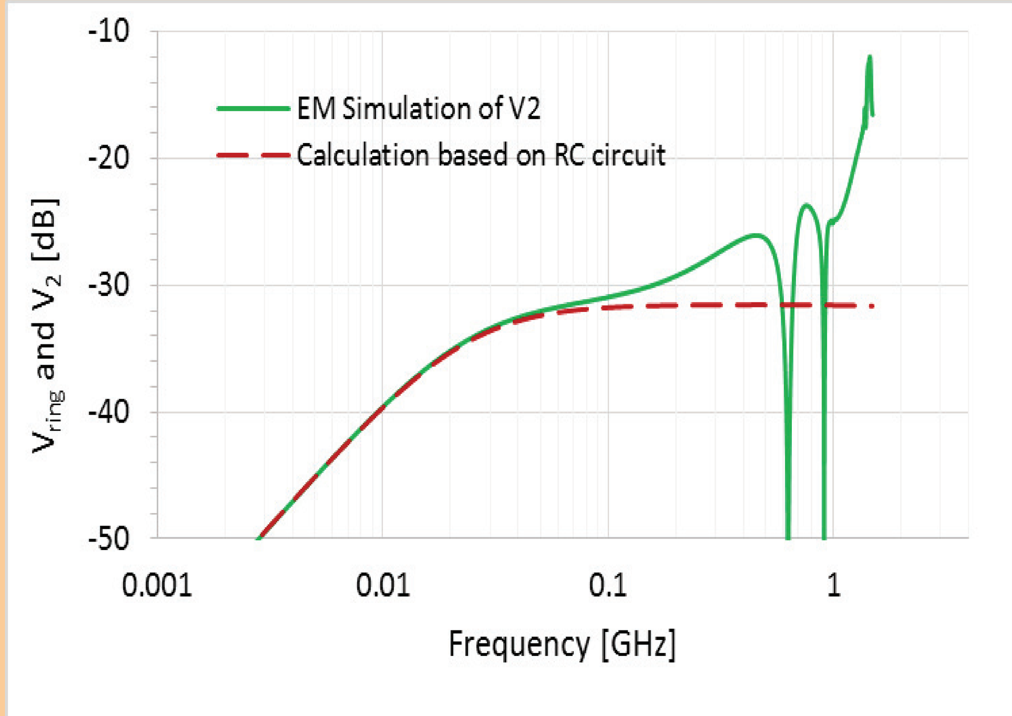
$$V_{ring} = 2R_{ring} I_{wire} \sin\frac{\omega l_{eff}}{2c}\left(1+\frac{1}{\beta}\right)$$

$$R_{ring} = \frac{R}{1+j\omega RC}$$

Fit Analytical Model with Simulation to Get L_{eff}

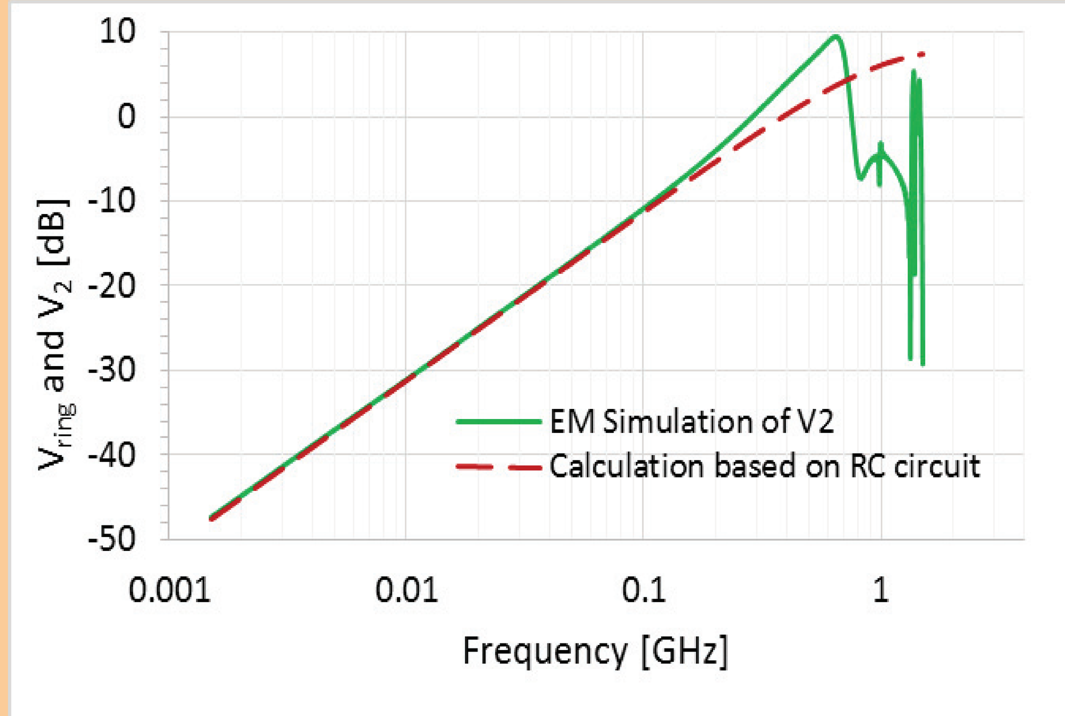
For complete LMR structure, C is calculated to be 150 pf. Actual niobium ring is 5mm.

C = 150pf; R = 50 Ф; β = 1.
Model matches simulation if L_{eff} = 8.5 mm.
Vring → 0 when f → 17.6 GHz.



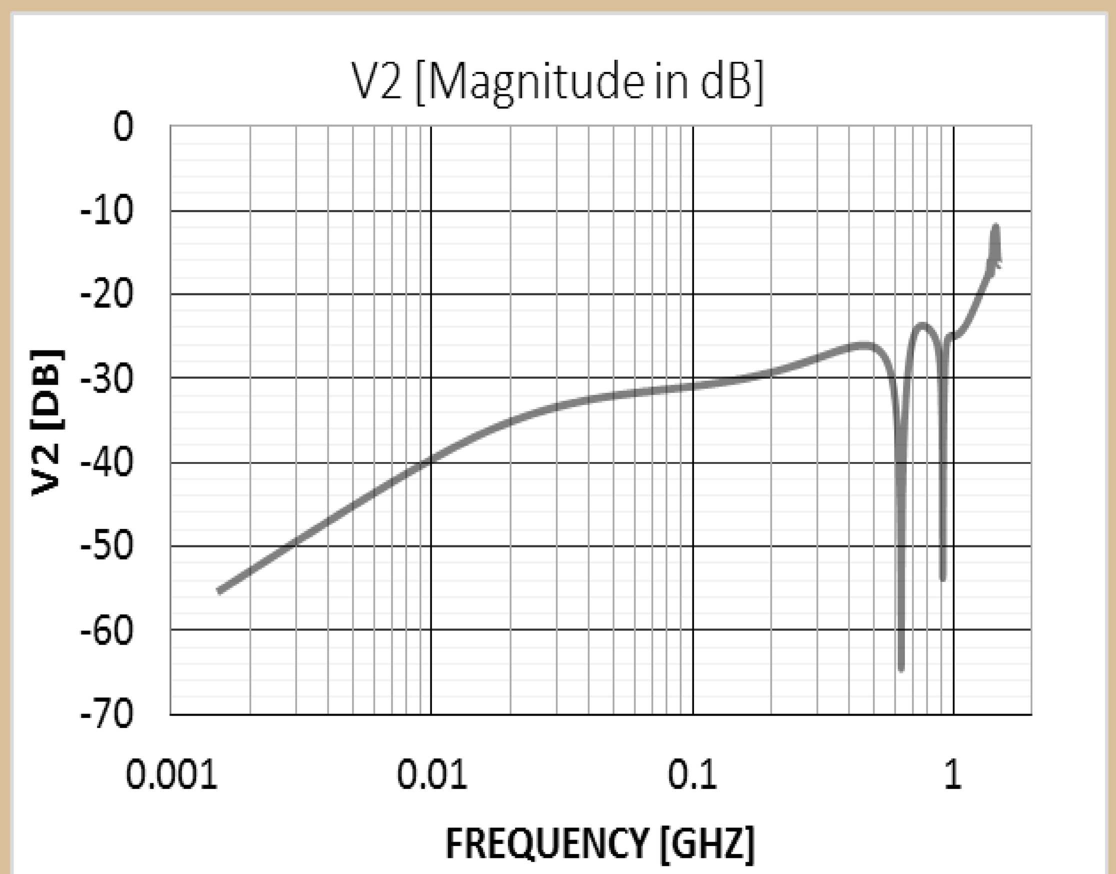
For Niobium intercept only, C is 3 pf . Corner frequency of RC circuit is 1.2 GHz.

Model matches simulation if L_{eff} = 21 mm.
Vring → 0 when f → 7.1 GHz.

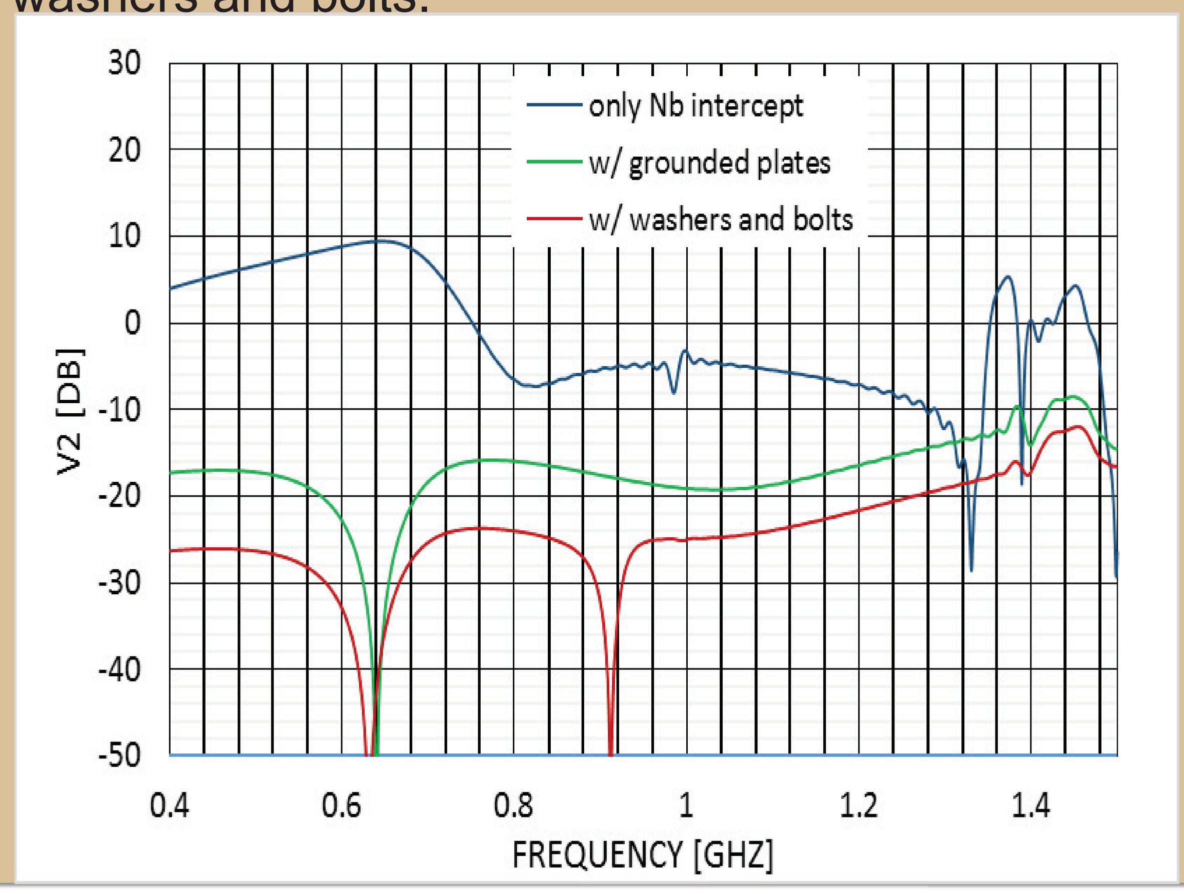


Simulated AC Response for Gaussian Excitation

Fundamental frequency of the box is f_{TM011}= 0.621GHz. Corner frequency for LMR RC circuit is f_{LMR} ≈ 0.021GHz. The oscillations around 1GHz should be induced by the box.



Comparison of output voltages with different structures of LMR. Different colours corresponds to a) only niobium intercept, b) adding grounded copper plates, c) adding washers and bolts.

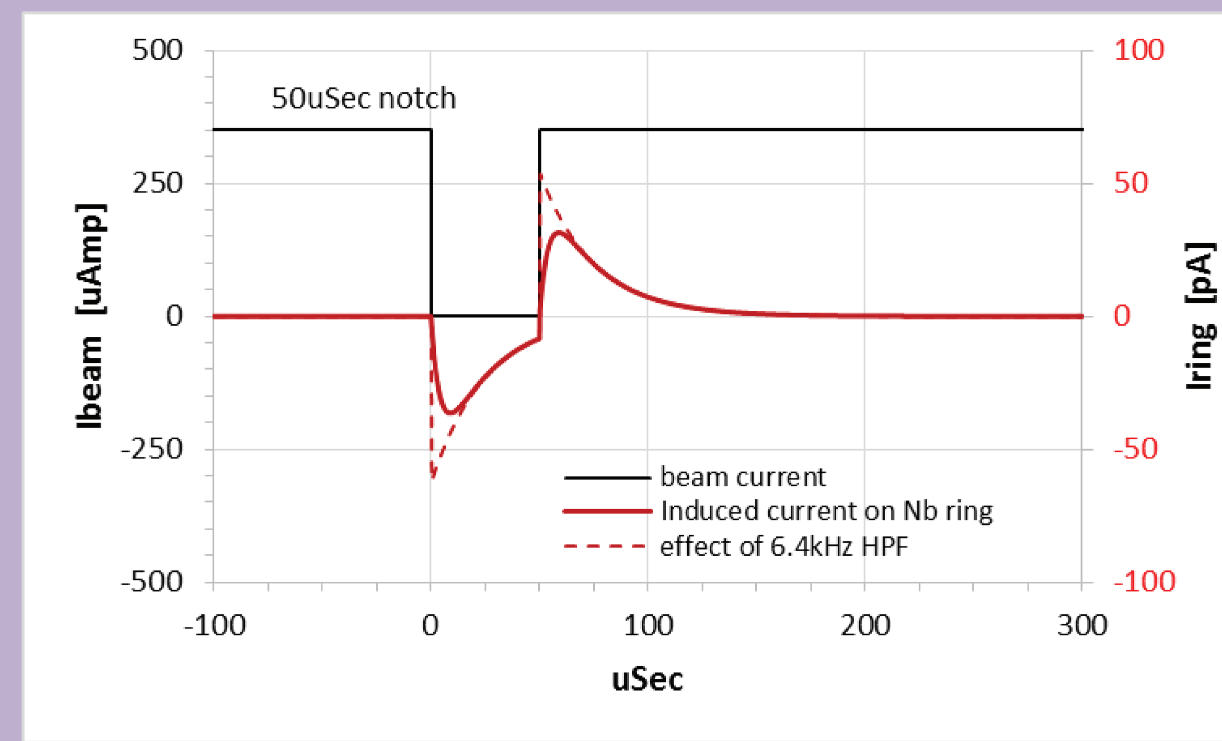


Estimation of I_{ring} by 50μs Beam Notch @ 100Hz

$$I_{notch}(\omega) = 2I_{avg}\frac{\Delta t_{Notch}}{T}\frac{\sin\left(\frac{\omega\Delta t_{Notch}}{2}\right)}{\frac{\omega\Delta t_{Notch}}{2}}$$

$$\frac{I_{ring}}{I_{beam}} = 2\sin\frac{\omega l}{2c}\left(1+\frac{1}{\beta}\right) \approx \frac{\omega l}{c}\left(1+\frac{1}{\beta}\right)$$

$$I_{ring} = \frac{1}{2}\frac{I_{ring}}{I_{beam}} I_{notch}$$



The I_{ring} / I_{notch} could be modeled as a 6.4kHz high pass filter (HPF). Combined with the 33kHz LPF that we plan to use, the final induced current will be ~33pA. Compared with LMR desired detection limit 100 ± 50 pA, it is still tolerable. It, however, brings some fake background when we take the samples in the notch for background subtraction. Integration in an extended time could help.

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