Description of the Sensor Correction FIR & IIR Filter Components

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1 Summary

We describe the components used to implement the FIR filter for the sensor correction used by HEPI to isolation the platform from the microseismic motion. The design of the basic FIR filter was done by Wensheng Hua, and described in his thesis. This document merely describes the necessary companion IIR filters used to complete the sensor correction path.

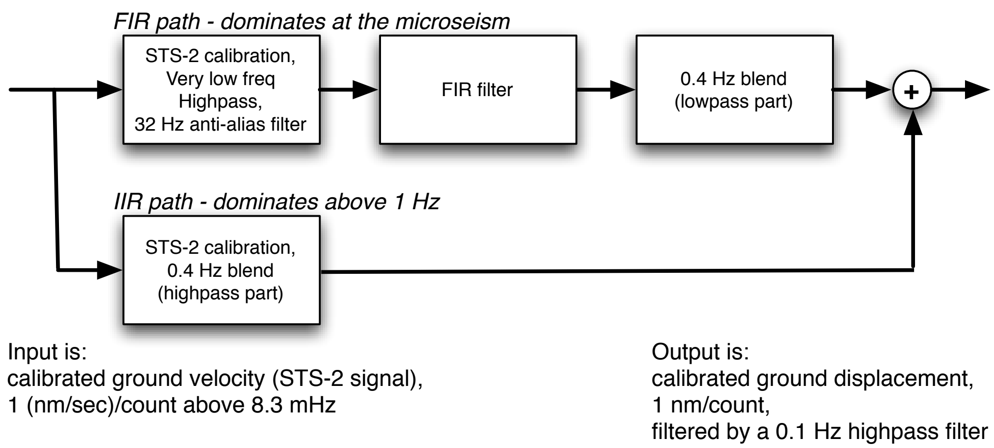

Figure 1: Components and flow for the sensor correction path

The sensor correction block calculates the signal to be added to the in-loop displacement sensor. The goal is to calculate the ground displacement and highpass filter it so we accurately pass the ground displacement at the microseismic peak and higher frequencies, but we do not pass the ground tilt, which dominates the horizontal signals at lower frequencies. The design of the 'optimal' filter for this is described in Wensheng Hua's thesis. A convex optimization technique was used to calculate the 'optimal' FIR filter, but the resulting filter is very computationally intensive, so a set of tricks are used to make the system realizable. Those tricks include the use of IIR filters to accompany the basic FIR filter. Figure 2 compares the basic FIR response to the final highpass consisting of the FIR and the IIR companion filters. The response near the microseism is the same, but the companion filters clean up the response below 10 mHz and above 1 Hz.

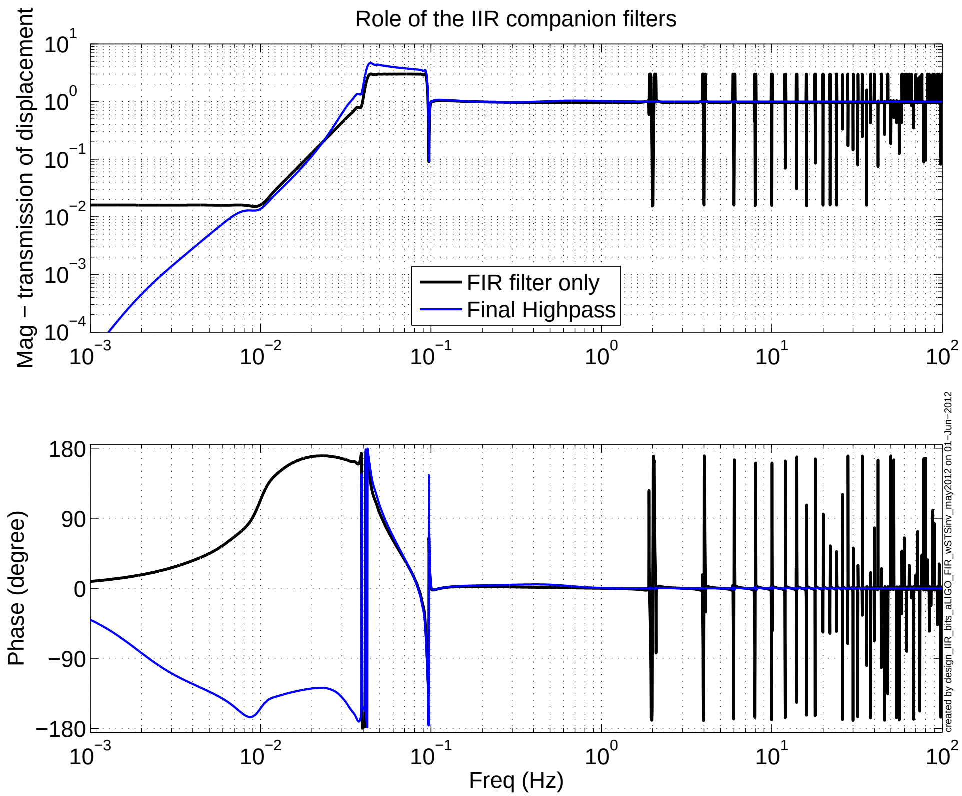

Figure 2: Comparison of the raw FIR filter and the Final Highpass. The Final Highpass uses both the FIR and several IIR companions filters.

2 The Parts

2.1 The parallel FIR and IIR paths

Conceptually, the sensor correction path first converts the calibrated STS-2 velocity signal into displacement, and then it highpass filters the displacement signal. [1] In reality, the calibrated STS-2 velocity signal is sent to two parallel paths, an FIR path and an IIR path. Each path inverts the STS-2 signal into displacement, and then the FIR path computes the low frequency part of the final highpass filter, and the IIR path computes the high

[1]The calibrated STS-2 signal is 1 count/(nm/sec) above 8.33 mHz, with two zeros at DC and two poles at 8.33 mHz. This is just a gain scaling of the original STS-2 response.

frequency part of the final highpass filter. The 0.4 Hz blend filter used to combine the low frequency signals from the FIR path with the high frequency path is shown in figure 3.

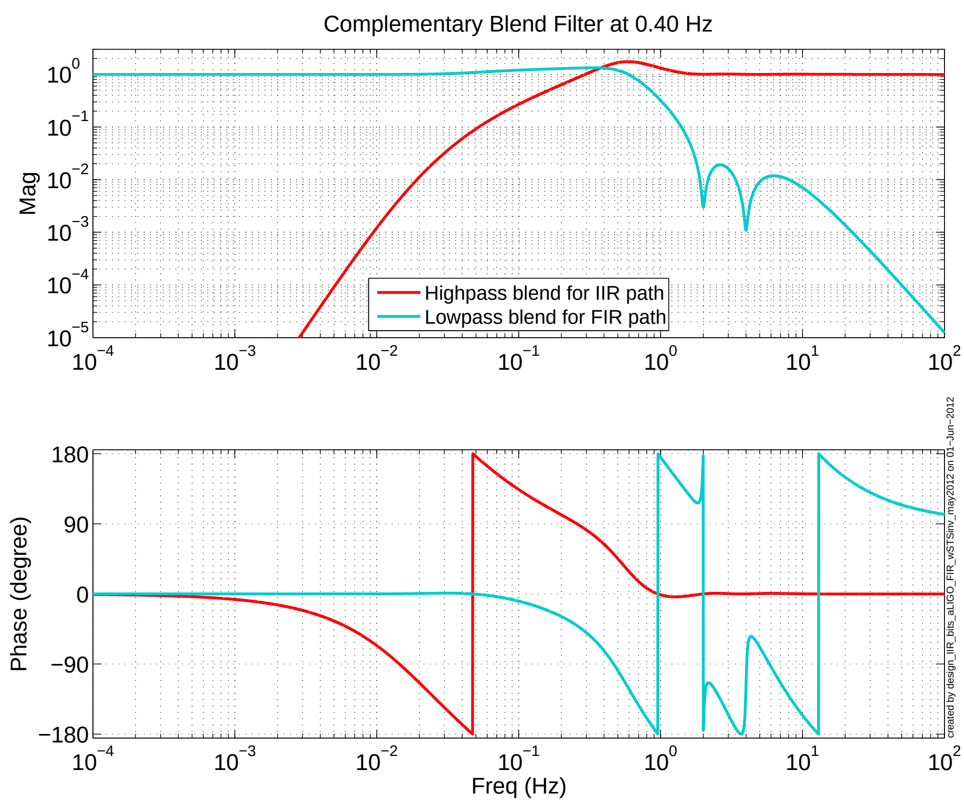

Figure 3: Complementary blend filters used to combine the low frequency signals from the FIR path with the high frequency signals in the IIR path.

2.2 The FIR path

The FIR path computes the sensor correction signal below about 0.4 Hz. The first block of the FIR path (module 0 in the MEDM screen) is shown in figure 4. This block has 3 jobs. First, it inverts the STS-2 response, so we have a displacement signal. Second, it applies a very low frequency highpass filter. This highpass filter must have at least 4 DC zeros, so that we have an AC coupled system (the STS-2 inversion has 3 DC poles). The very low frequency highpass also assists the FIR filter by rolling off the very low frequency signals. The frequency response of FIR filters for periods longer than the filter history is fixed at some DC value, so IIR filters are better suited for very low frequency roll off. Finally, module zero has an anti-alias filter at 32 Hz. The FIR filter samples at 64 samples/ sec. The anti-alias filter is a 4th order elliptic with zeros at 64 and 128 Hz, and should be very good at keeping aliased noise out of the few Hz around DC.

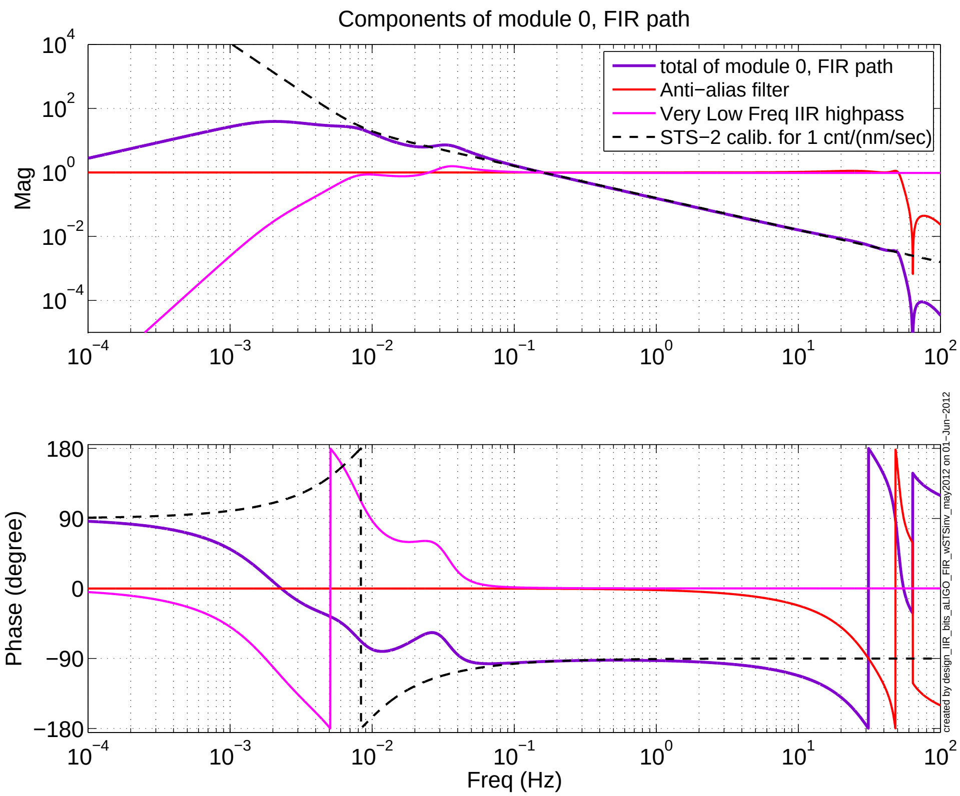

Figure 4: Module 0 of the FIR path. This filter set converts the STS-2 into displacement, rolls off the very low frequency signals, and has an anti-alias filter for the FIR.

The second module is the polyphase FIR filter.

The third module in the FIR path is the lowpass half of a complementary filter with a blend frequency of 0.4 Hz, and notches at 2 Hz and 4 Hz to help suppress the bumps in the FIR response. Figure **??** shows the filters in each of the 3 modules, and their product.

2.3 The IIR path

The IIR path is very simple. It inverts the STS-2 response, so we have a displacement signal, and multiplies that by the highpass part of the 0.4 Hz blend filter. The components are shown in figure 5.

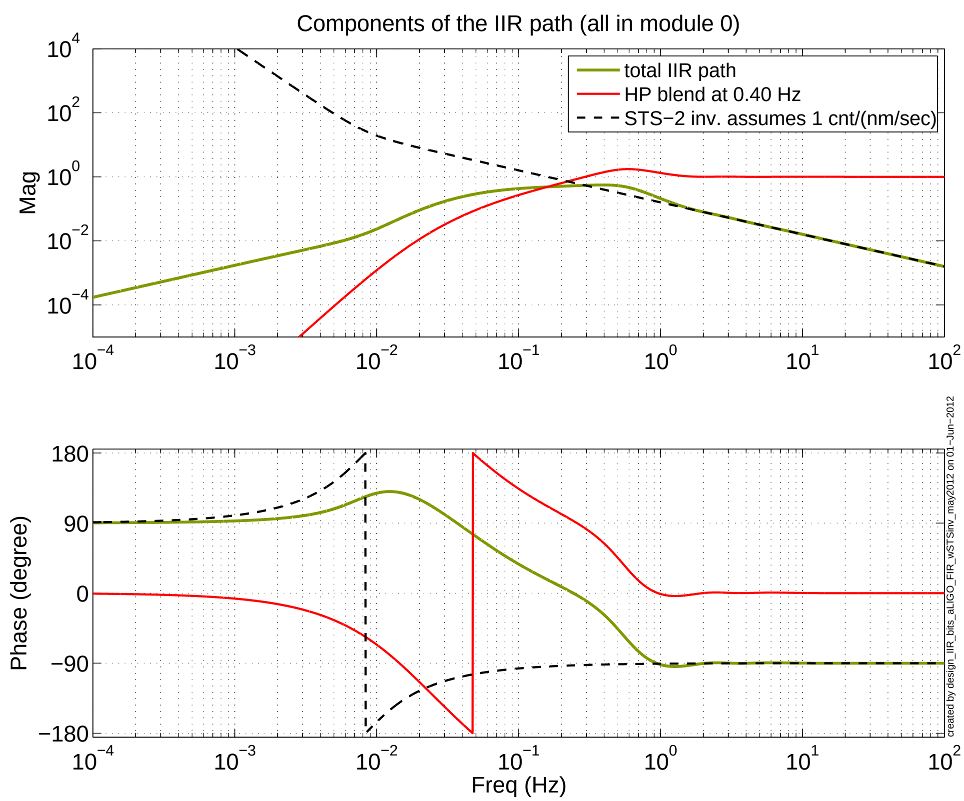

Figure 5: The IIR path. This filter converts the STS-2 into displacement and filters the resulting displacement signal with the highpass part of the 0.4 Hz blend filter.

2.4 Combined Paths

In figure 6 we can see the final transmission of the sensor correction filter. This is the sum of the FIR and IIR paths, and is also the product of the STS-2 sensor inversion and the final highpass filter from figure 2.

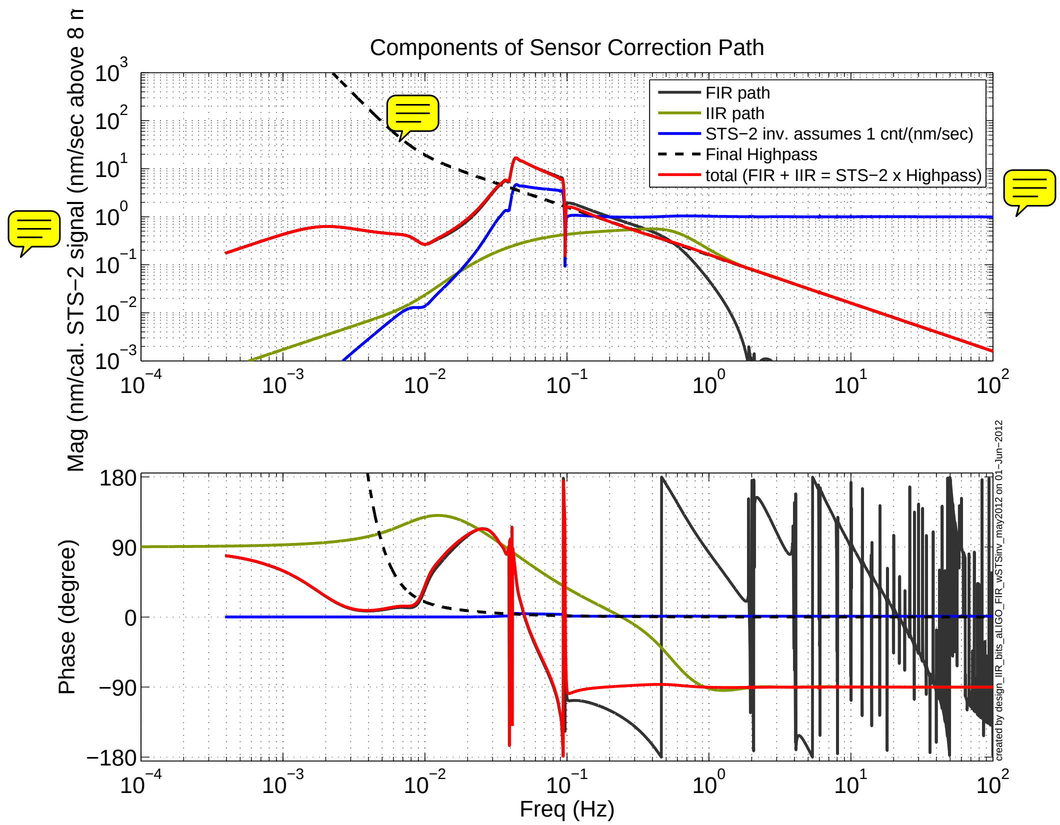

Figure 6: The final filter for sensor correction. This is the sum of the FIR and IIR paths. It is also the product of the STS-2 sensor inversion and the final highpass filter.

2.5 Final Performance Estimate and Matching

If we have properly calibrated the STS-2 and the CPS, and the transmission of ground motion to the HEPI structure is unity, then the performance of the sensor correction should be the difference between the final highpass filter and 1. It should be clear that changing the IIR filters will change the performance. In particular, small phase errors can easily cause performance changes. The performance estimate is shown below in figure 7. If the performance is not this good, there is a set of *matching filters* which can be used to try and compensate for the difference.

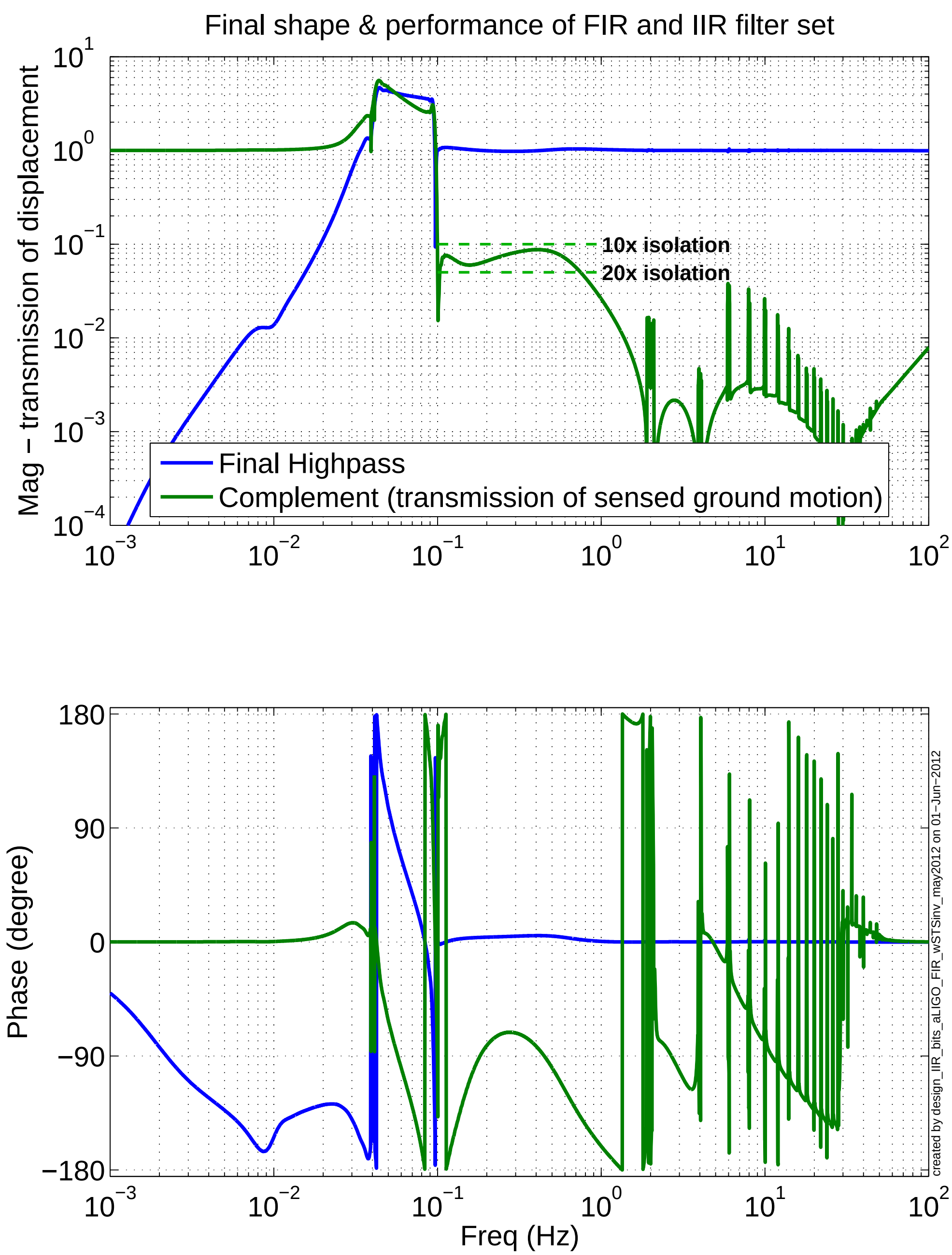

Figure 7: The final performance estimate for the sensor correction signals.