Estimate of Magnetometer Contribution to S5 H1L1 Isotropic Estimate

S. Kandhasamy and V. Mandic

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This note attempts to estimate the level of correlations between H1 and L1 h(t) channels due to the magnetic contamination. For this purpose, we will calculate the coherence between H1 (L1) and a coil magnetometer at one of the sites. The basic idea is:

$$Y(f) = \frac{T}{2} P_{12}(f) Q(f) df \tag{1}$$

$$\sigma^2(f) = \frac{T}{4} P_1(f) P_2(f) Q^2(f) df \tag{2}$$

$$\begin{aligned} SNR(f) &= \frac{Y(f)}{\sigma(f)} = \sqrt{Tdf}\frac{P_{12}(f)}{\sqrt{P_1(f)P_2(f)}} \\ &= \sqrt{Tdf}\gamma(f) \end{aligned} \tag{3}$$

where $P_{12}(f)$ is the cross-spectral density between two interferometers, P_i is the power spectral density for interferometer i, Q is the optimal filter and γ is the (complex) coherence. If we can estimate the magnetic contribution to the coherence, γ_M, then we can estimate the magnetic contribution to the stochastic SNR using the last equation, where T is the total exposure time. The magnetic contribution to the coherence can be estimated as usual:

$$\gamma_M(f) \approx \gamma_{H1,M}\gamma_{L1,M} \tag{4}$$

where M stands for magnetometer, and $H1$ and $L1$ for the h(t) channels.

In this note, we use the coil magnetometer in the x-direction at both sites (COIL_MAGX). Each magnetometer can be used to produce an estimate of SNR_M, so with two of them we can compare two estimates. Figure 1 shows the coherence ($\Gamma = |\gamma|^2$) for four combinations: H1 h(t) with LHO COIL_MAGX, L1 h(t) with LHO COIL_MAGX, H1 h(t) with LLO COIL_MAGX, L1 h(t) with LLO COIL_MAGX. Note that the coherence calculations between L1 h(t) and both magnetometers are elevated at frequencies around 100 Hz, while H1 h(t) does not seem to be correlated with

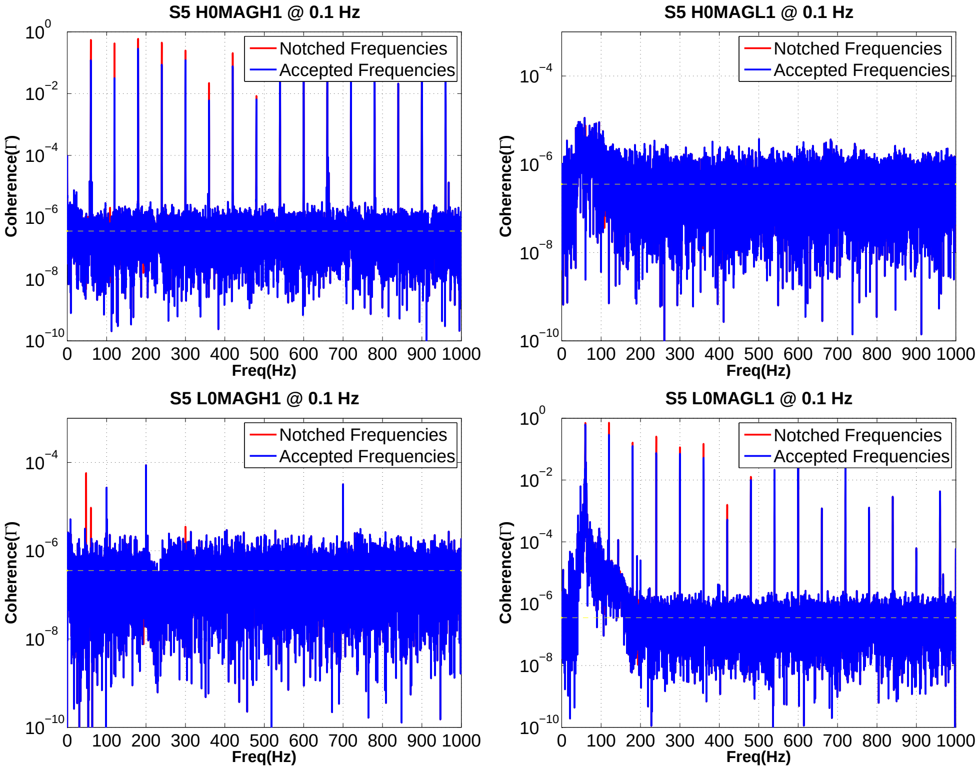

Figure 1: Coherence between magnetometers and GW channels.

either magnetometer. It is, of course, a question whether the observed deviations above the noise floor are real or not. In the past, large glitches in the data were found to cause such deviations. Figure 2 shows the cumulative trends in coherence calculations including L1 h(t). No obvious discontinuities are observed, which hints that the observed coherence levels are real or that there is a more serious problem with the data, which is not limited to a handful of glitches.

Nevertheless, we can proceed with the calculation of the SNR_M. Figure 3 shows $SNR_M(f)$ for the two cases. In the worst case, some of the frequencies reach SNR level of 10^{-2}, and usually the contribution is at the level $< 10^{-3}$. We can also multiply this with $\sigma_Y(f)$ estimated previously by stochastic.m, and integrate over frequency - the results are:

- Using H0 magnetometer $Y_M = (-1.6 - 3.5i) \times 10^{-9}$
- Using L0 magnetometer $Y_M = (-0.47 + 1.3i) \times 10^{-8}$

These estimates are 3 orders of magnitude below the S5 LHO-LLO upper limit (5.9×10^{-6}). Note also that the coherence levels for H1 h(t) were consistent with noise, so the actual contamination is likely lower. One could

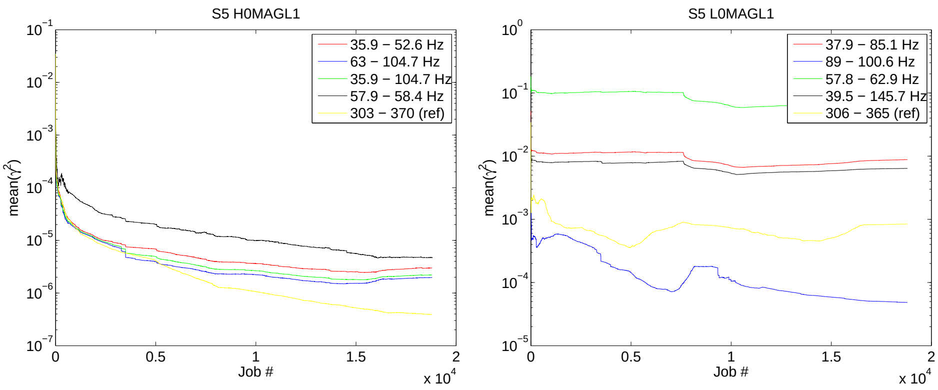

Figure 2: Trends of coherence calculations including L1 h(t).

imagine repeating the calculation using all other available magnetometers, and also performing a much more careful study of the quality of magnetometer data. However, this is unlikely to change the conclusion of this study: the magnetic contamination should not be a problem for the S5 LHO-LLO isotropic stochastic search.

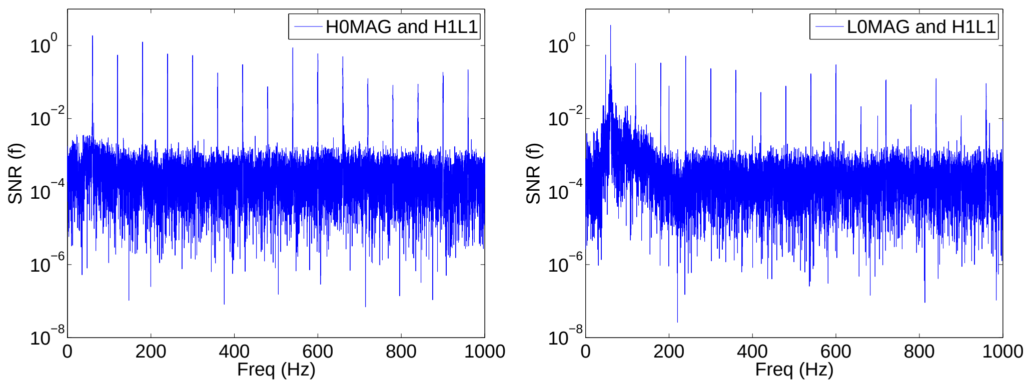

Figure 3: Estimates of $SNR_M(f)$ using the LHO and LLO magnetometers. Absolute value of the real part of SNR_M is shown.