Noise in IFO subsystems

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1 RF Noise in Sensing and Control Subsystem

Prototypes of the revised Balun design have been assembled and tested. First we drafted and ordered a replacement circuit board for the transformer. In the revised board we have moved the transformer to accommodate the placement of a surface mount UMCC connector to facilitate using a coaxial transmission line instead of the original unshielded wires. This required replacing the male N-type to solder cup connector with an N-type to SMA connector. Second, we modified the design of the circuit board end piece by adding solder pads for more capacitors. Finally, we replaced the circuit board on the male end of the Balun with a solid conductive plate. The conductive plate was a hand made copper end piece, however we are evaluating an aluminum end piece alternative that can be ordered from a supplier.

The prototype baluns demonstrate significant attenuation of RF noise in the ISC racks, as shown by measurements of noise before and after replacement of an original balun by the new prototype balun. Once the change request for the design is approved we will fabricate 10 more modified baluns for installation in the ISC racks.

Having reduced the noise resulting from the coupling of neighboring unmodified baluns we can now see in the noise spectrum signals that were previously obfuscated. In particular we now see a 79 MHz peak in the spectrum of the lines in ISC Rack R1. The 79 MHz signal is used by the PSL, and the voltage controlled oscillator that supplies the signal is located in the ISC racks. It is unclear how the signal is coupling to the ISC racks, but we suspect the coupling is happening in the PSL compartment.

2 Phase Noise

In the data acquisition system, concern has been raised about jitter of the GPS 1 PPS signal causing phase noise on the digital output of the ADC of the DARM signal. Since the 1 PPS signal is used to discipline an oven controlled oscillator (OCXO), which drives the clock of the ADC, the concern is that the jitter of the 1 PPS may cause the frequency of the clock to drift. This could cause variation in the sampling period of the ADC, generating phase noise in the output of the ADC.

A previous surf student characterized the 1 PPS jitter of our GPS receiver at LHO. He found that the 1 second interval is accurate to ± 40 ns. Since the ADC is clocked at 2^{14} Hz $= 16.384$ KHz, the nominal sampling period is about 61 μs, and 3 orders of magnitude larger than the noise. Because of the time scale separation between the jitter and the sampling period, it doesn't seem likely that this could cause be a significant source of noise on the final DARM signal. An approximation of the impact of phase-frequency noise on the clock was estimated by modeling the output of the ADC as $\sin(2\pi f_c(t + \Gamma \sin(2\pi f_n t)))$, where f_c is the actual frequency of a continuous wave signal, f_n is the frequency of the noise (variation in sampling period), Γ is the modulation index of approximately 40 ns. Using the Jacobi-Anger expansion of this signal we can see there is power transfered to sidebands at $f_c \pm f_n$. The amplitude of those signals are given by $J_1(2\pi\Gamma f_c)$. Since f_c for a continuous wave signal is generally less than 10 Khz we can put an upper bound of $20\log_{10}(.0013) \approx -58$ dBc on the side band amplitude. Since f_n is small (less than 1 Hz), the spectrum of the measured DARM signal would be a very narrow peak centered at the actual carrier frequency of the signal. Therefore, we see little reason to believe 1 PPS jitter could be a source of error in measurement of the DARM signal.

3 Spectral Leakage in FFT

Previous SURF students have developed a data analysis program that simulates an all sky search for a phase/frequency modulated continuous wave signal of unknown carrier and modulation frequencies, and unknown modulation index. The search attempts to correlate the spectrum of the DARM signal with these parameters by convolving the spectrum of the DARM signal with the terms from the frequency domain representation of the Jacobi-Anger expansion of the target signal.

The search returns all three parameters for a simulated signal, however it was found that the search was significantly hindered by noise in the spectrum of the simulated DARM signal, and failed to identify signals with irrational frequencies. Spectral leakage is generally a result of poor windowing of data. Since the Fourier transform treats the sampled data as a single period of a repeating signal, when the sample duration is not an integer multiple of the period of the signal, the effective repeating signal will have discontinuities in it. This sharp sudden change in the time domain representation results in broadband noise in the frequency domain known as spectral leakage.

This leakage coupled with the fact that frequency bins of the DFT are finite in width can cause signals at the edge of a frequency bin to disappear in the noise completely. Since irrational frequencies are in general approximated to a greater number of decimal places than the frequency bins they will tend to fall at the edge of bins. Hence, the search fails to identify these signals as well. In the remaining 3 weeks of the program we will explore possible solutions for minimizing this noise and increasing the efficiency of the search algorithm.