Radio Frequency Noise in IFO Sensing and Control System

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1 Background

Radio Frequency (RF) oscillators are utilized to generate RF signals for various systems in the IFO. For example, RF sidebands at 9 MHz and 40 MHz are used to generate an error signal for the length of the arm, to be fed back to the mirror position actuator for correction. This RF noise can cause whistles in the response spectrum of the IFO, or generate incorrect feedback in the control system causing the IFO to lose lock. Previous investigation at LHO has found that the transmission lines in the ISC racks exhibit cross talk between these RF signals. Specifically, it was found that the ground isolation transformers, known as baluns, were the primary cause of RF radiation and coupling between lines.

A balun is a class of devices that utilize a transformer to convert a signal from a balanced representation, such as a differential signal transmitted on a twisted pair of conductors, to an unbalanced representation, such as those propagated by coaxial transmission lines. The name "balun" is a portmanteau of "balanced to unbalanced". The particular baluns found on the patch panels of the ISC racks are coaxial to coaxial transformers designed to block any DC offset on the RF signals and DC or 60 Hz noise between separate grounds of the racks. The purpose of the present investigation is to develop repeatable balun modification procedures that provide maximum attenuation of RF noise.

2 Investigation

A custom test lead was built to probe the baluns without removing them from the system. The devices used two wrap around leads to measure the potential difference between the two isolated grounds as read at the back shell of the two coaxial connectors of the balun. With a spectrum analyzer and this test lead it was possible to measure the spectrum of the noise radiating into or out of the line. In principle the back shells of both connectors should be capacitively coupled such that all steady state DC is blocked and any RF signals are shorted to ground. This means any RF signal measured across the back shells of the balun is being radiated into or out of the enclosed line and is not adequately being shorted to ground.

A test bench investigation of the devices was conducted using the same measurement device. The balun is connected to the output of a network analyzer, the opposite end is terminated (50 Ω), and the test lead is connected to the back shell of both sides of the balun. The response spectrum of the balun was measured and compared to multiple prototypes of replacement balun. See Figure 1.

A copper plate was added to each test balun to ensure the back shell of one connector was connected to body of the balun. The circuit board on the opposite end was fitted with surface mount capacitors to ensure capacitive coupling of the grounds. To verify the efficacy of our measurement technique, measurements of a 9 Mhz line and a neighboring 118 Mhz line were taken before and after replacing the 118 MHz balun with a modified balun. See Figures 2, 3. These measurements were compared to and agreed with the spectrum measured on an antenna placed next to the electronics rack. See Figures 4, and 5.

3 Results

Baluns of various capacitances were tested. While some variation was measured as capacitance changed, a greater variation was observed when the configuration of the inner conductor was changed. This suggests the inductance of the wires inside the balun are primarily responsible for radiation. This inductance is determined by the geometry of the conductors (size, shape, and placement).

The greatest noise attenuation was achieved in the 130 μF balun by replacing a stranded conductor ground wire with copper braiding, however attempts to replicate this configuration were unsuccessful. Other attempts at modification included replacing the ground wire with copper tubing, and replacing both wires with coax cabling.

Significant attenuation (replace with quantitative result) was achieved in the prototype using a coaxial transmission line. This prototype was revised by replacing the solder cup N type bulkhead connector with a N type to SMA bulkhead adapter, allowing the inside conductor to be replaced with an SMA terminated coax line. This was found to be significantly more repeatable. The unterminated end of the coaxial line was split; the center conductor was connected to the positive end of the transformer, and the shielding to the ground end of the transformer. We found that replacing the balun on the 118 Mhz line with a modified balun greatly attenuated the 118 MHz noise on the neighboring 9 MHz line.

4 Future Work

A redesign of the printed circuit board inside the balun to better accommodate terminated coaxial transmission lines has been drafted and will be ordered in the future. We will be placing a surface mount UMCC connector on the transformer circuit board so the coax line may be terminated on both ends, further increasing reproducibility of results.

Additional N-SMA bulkhead fittings have been ordered, and when parts arrive we will continue to build more of the prototype balun in order to verify it's reproducibility. Once a full set of replacement baluns are built, they will be characterized for insertion loss and phase shift as a function of frequency, and phased into replacement of the existing baluns.

Once the balun investigation is concluded a thorough investigation of phase noise in the GPS disciplined oscillators will be conducted. It has been observed that oscillators disciplined by the same GPS receiver exhibit a time varying phase difference.

It is thought that this phase noise can result in the accumulation of timing errors in long term searches such as continues wave searches. We will investigate the effect this phase noise has on the IFO and the cause of the noise. Corrective actions will be assessed as more information becomes available.

5 Figures

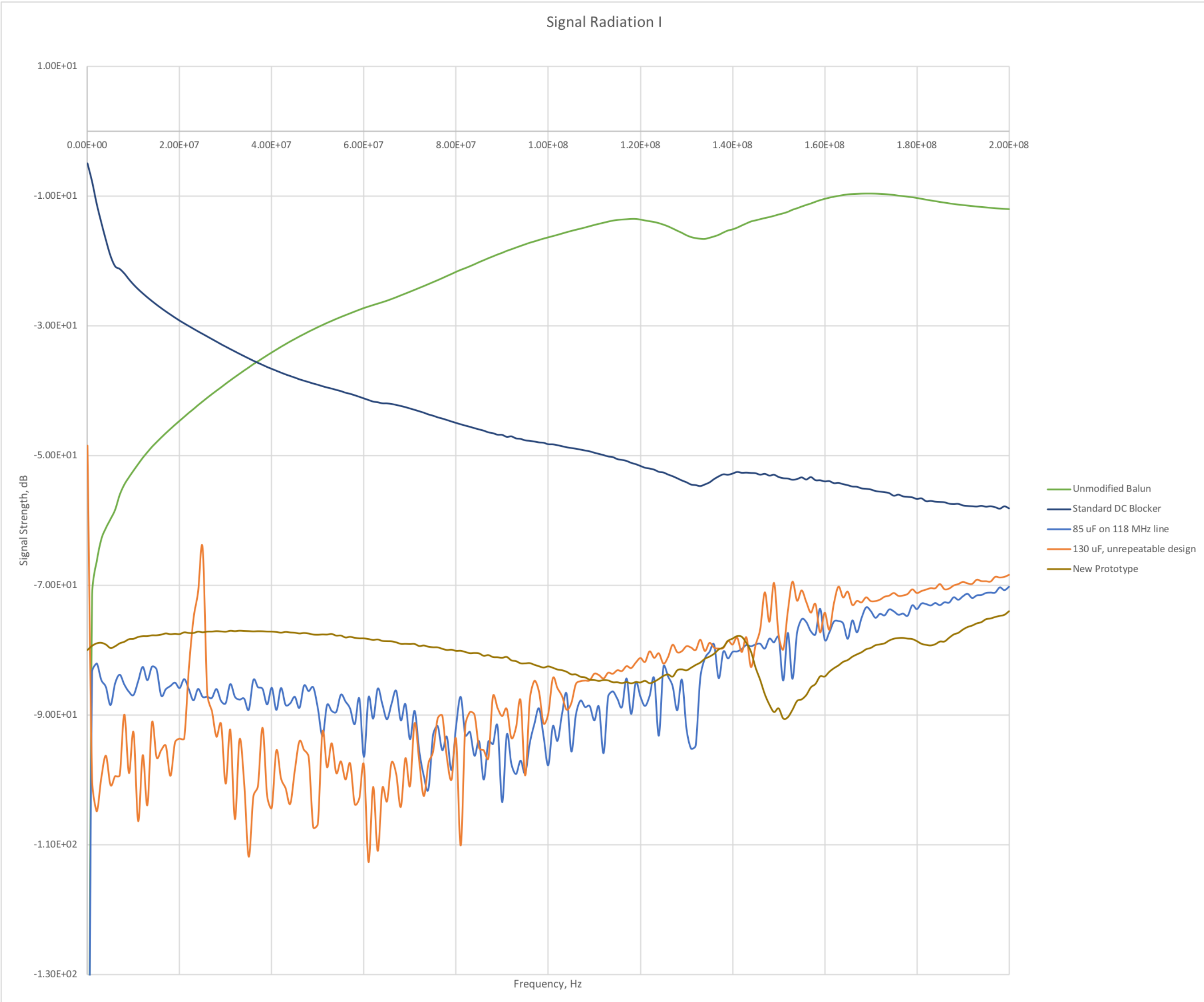

Figure 1: Balun Attenuation, Test Bench

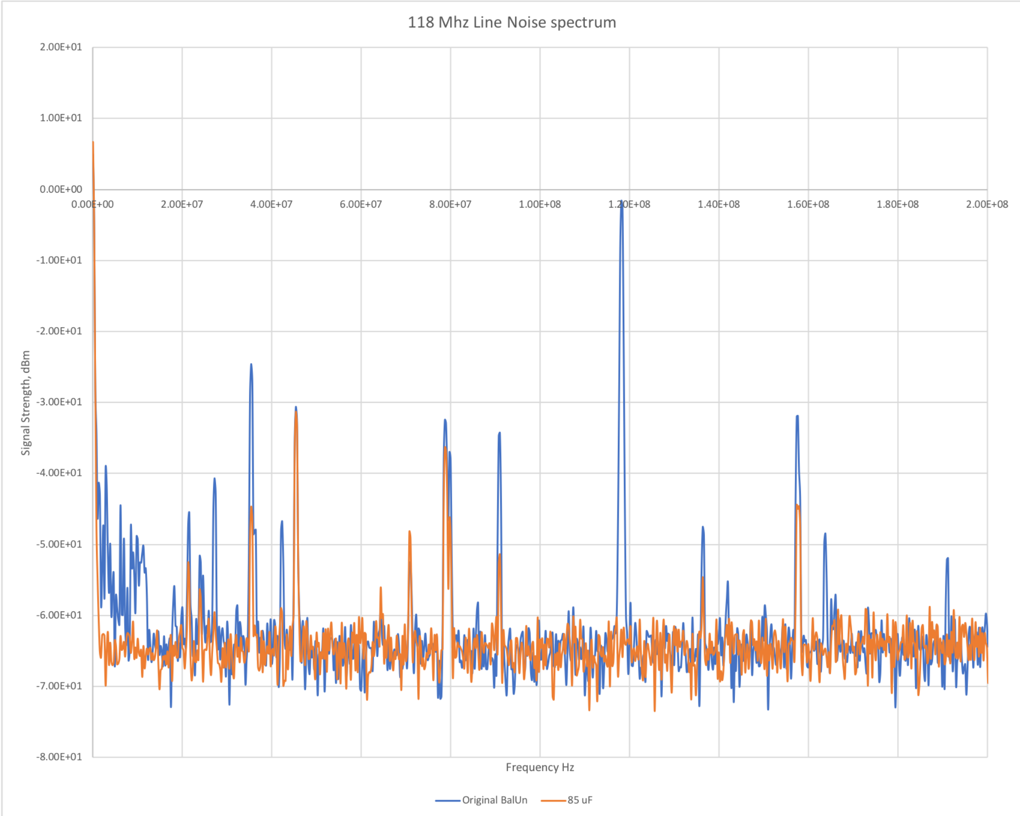

Figure 2: Balun Noise, 118 MHz line

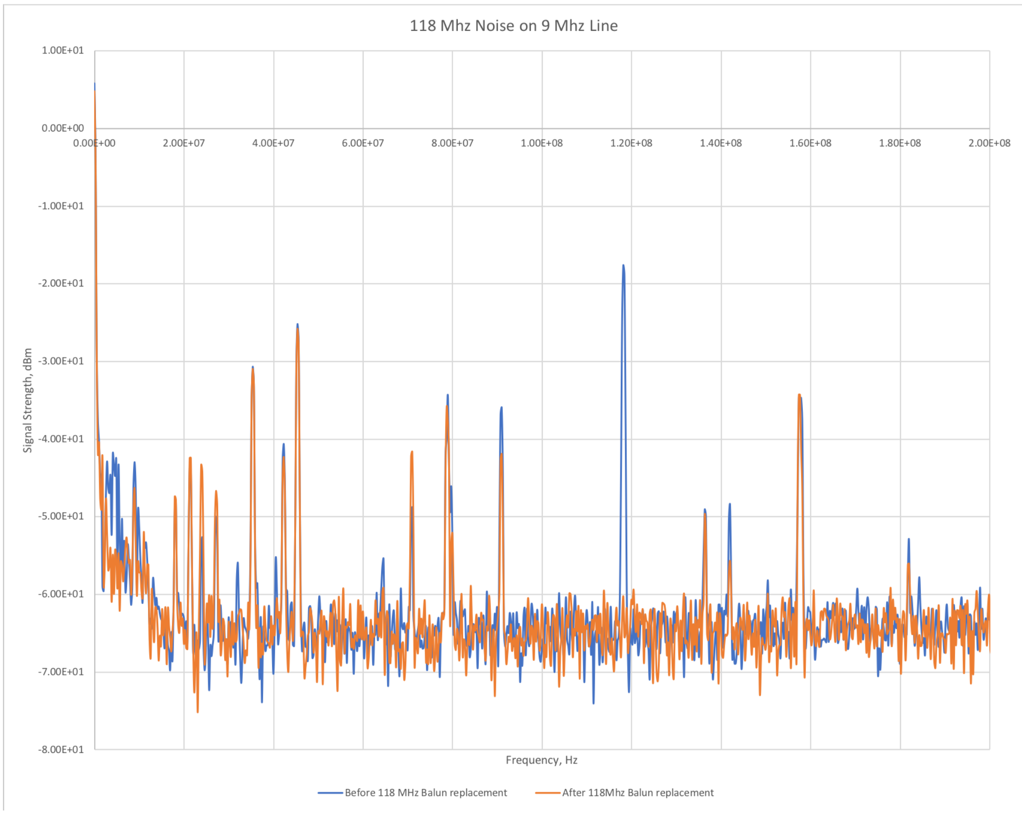

Figure 3: Balun Noise, 9 MHz line

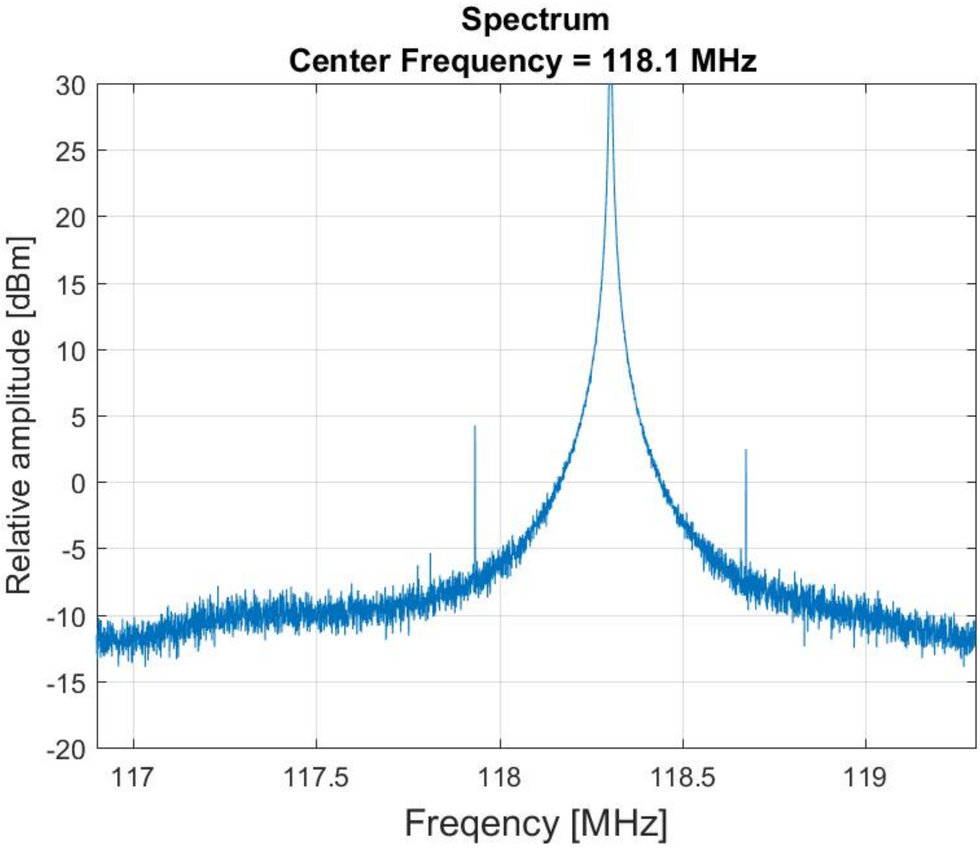

Figure 4: 118 MHz RF in Rack, Unmodified Balun

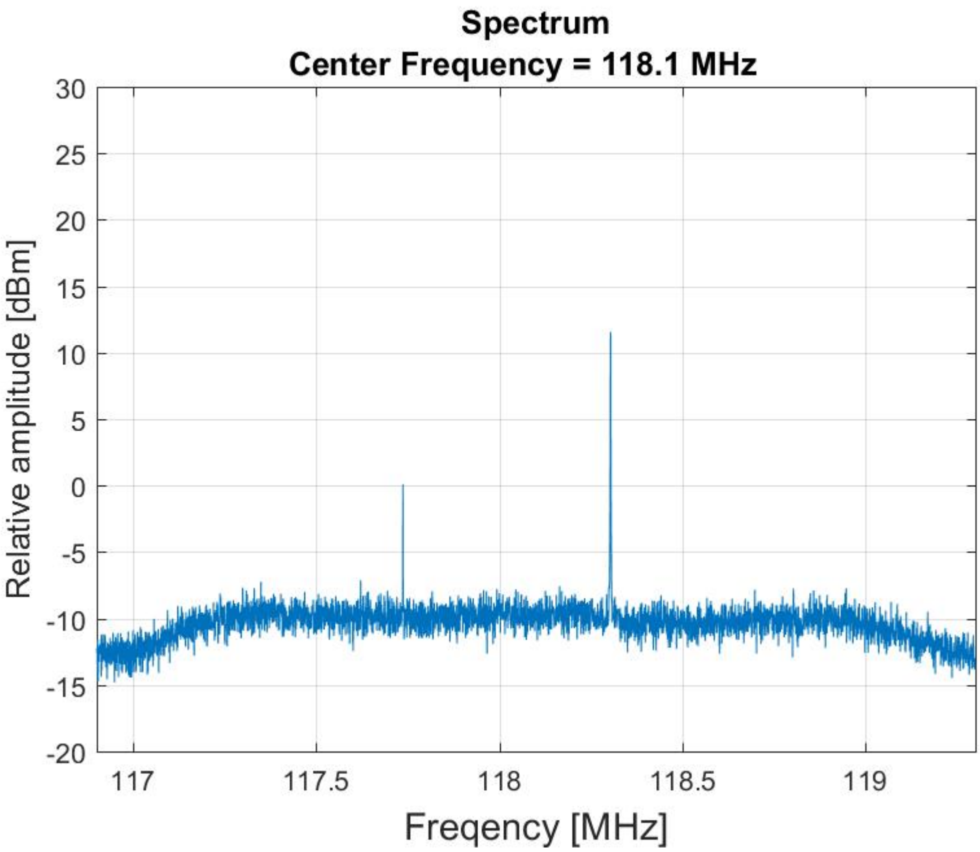

Figure 5: 118 MHz RF in Rack, Modified Balun