PEM Installation Procedures

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1 Introduction

The Physical Environment Monitoring (PEM) system is an array of accelerometers, magnetometers, seismometers and other sensors used to detect environmental noise that could couple to the interferometer's signal. A full list of the PEM sensors to be installed in aLIGO can be found on the PEM website. These sensors are needed in order to evaluate whether a spike in the signal is caused by a passing gravitational or simply by environmental noise. The PEM system can also be used to locate areas where noise can couple with the detector output. By locating the sensors on a grid, we can use the PEM system to calculate the propagation speed and direction of passing signals, e.g. seismic vibrations. At LHO, we have installed accelerometers, microphones, and magnetometers for the PEM system. In addition to installation work, we developed a technique to be used to determine the coordinates of the various sensors.

2 Installation

2.1 Accelerometers

Accelerometers are to be mounted throughout the entire site. Each accelerometer only measures vibrations in a single direction. This is fine in some locations, such as floor accelerometers that only need to be sensitive to the z direction or accelerometers mounted on the beam tube which look at radial directions. However, on most BSC we install 3 accelerometers to measure the x, y, and z directions. The z accelerometer should be mounted on the bottom of BSC as close to the center as possible as the center is most perpendicular to the z direction. However, on some BSC the underside is inaccessible. In these cases the accelerometer should be mounted on the topside of the BSC, once again in the area perpendicular to the z direction. On the direction of the beam tube that the BSC is located on (e.g. the x direction on the x arm), the accelerometer should be mounted on the flange connection the beam tube to the BSC. The accelerometer should be close to the beam tube, approximately one inch away, to ensure that the accelerometer is not accidentally knocked off. In the direction perpendicular to the beam tube (e.g. the y direction on the x arm), the accelerometer should be mounted on one of the BSC doors in the area just below the central port, as this surface is most perpendicular to the desired direction. The accelerometer should be mounted on the door that is least likely to be used, as the accelerometer can be knocked off or damaged during removal of the BSC door.

We use epoxy to mount the accelerometers. Devcon brand 5-minute epoxy was found to be the most effective. In order to electrically insulate the accelerometer from whatever surface it is mounted on, we first epoxy the accelerometer to a piece of cling wrap and then epoxy the cling wrap to the surface. In addition, an instrument is needed for mixing and spreading the epoxy. We used the stick side of a cotton swab cut in half (not the side with the cotton tip!). Other materials needed are a pair of scissors to cut the cling wrap, a piece of paper to mix the epoxy on, and tape to hold the accelerometer in place. The procedure for mounting the accelerometer is as follows:

1. Cut a square out of the cling wrap slightly larger than the accelerometer base, approximately 1¡" x 1¡".

2. Put a small amount of epoxy on the paper and mix thoroughly.

3. Apply a thin, even layer of epoxy to the bottom of the accelerometer.

4. Place the epoxied side of the accelerometer onto the center of the cling wrap square.

5. Smooth out any folds or air bubbles between the cling wrap and accelerometer surface.

6. Apply a thin, even layer of epoxy to the cling wrap underneath the accelerometer.

7. Place the accelerometer on the surface it is to be mounted on. Hold it in place for 2 minutes in order to let the epoxy set.

8. Tape the accelerometer to the surface to hold it in place. Using 2 pieces of tape and making an "X" over the accelerometer will ensure that it stays.

9. Wait at least an hour before removing the tape.

2.2 Microphones

Microphones are needed for the PEM system to detect acoustic noise. In certain places, for example in the EBAYs, microphones can simply be hung from the cable trays. However, in many locations along the beam tube we cannot use the cable trays. In these locations, we suspended the microphone from a metal bar, about 2 feet in length. The bar was attached using a C-clamp to the mount on the beam tube used to compress the bellows. We did not install the microphone on the bellows compression mounts closest to the HAM as the microphone would hang in front of the HAM door which could provide difficulties when opening the door. Instead we installed the microphone on the next bellows compression mount. The bar should be installed sticking out at a flat horizontal angle parallel to the ground. To attach the microphone to the bar, we placed adhesive cable tie holders on the underside of the beam. The microphone wire was then attached to these cable tie holders using cable zip ties. The microphone head was allowed to dangle about 2 feet below the bar to isolate it from any vibrations.

2.3 Magnetometers

Magnetometers are mounted in the electronics bay (EBAY) near the SEI and SUS racks. Since magnetometers can pick up noise if they are located near conductive materials, we used ij" inner diameter PVC piping to install the magnetometers. The EBAY racks contain holes on the outer casing that the ij" piping fit into. We cut the piping into 22 $\frac{3}{8}$" sections as this size was able to be inserted and removed from the racks only with some bending of the pipe. At each end, we drilled holes through the pipe about 2" from the end. Cable zip ties were threaded through these holes and into adhesive cable holders stuck to the sides of racks in order to prevent the pipe from rotating. The magnetometer was attached to the bottom of the pipe using 9 cable zip ties. This kept the magnetometer from rotating after being pushed on. The axes of the magnetometer must be aligned with the axes of the detector, but the markings on the magnetometer will not match the axes of the detector due to its orientation. Labels should be applied to both the magnetometer and the filter box specifying the corresponding axis in the detector system.

3 Position measurements

3.1 Bilateration

In addition to mounting the sensors, we also measured their positions in the detector coordinate system. Knowing these coordinates ements will allow us to measure the propagation speed and velocity of passing signals. In order to calculate this position, we used a technique known as bilateration to calculate the x and y coordinates. Bilateration uses distance measurements to 2 known positions to calculate the coordinates of an unknown position. If we know the distance between known point 1 and the unknown point is x, the unknown point must lie on the circle centered at point 1 with radius x. If the distance between known point 2 and the unknown point is y, the unknown point must also lie on the circle centered at point 2 with radius y. These 2 circles will intersect in 2 locations, either of which could be the unknown point. We can then tell by the relationship of the unknown point and the known points which of the 2 possibilities is correct as one will be in the wrong direction relative to the known points.

3.2 Monuments

Our known positions were the various monuments set up on the floor whose values are already recorded. Before using the monuments, we checked that the monuments' locations were self-consistent with each other by measuring the distances between the monuments and using bilateration. Monuments that were checked to be self-consistent with each other were marked "PEM OK." Some sensors (such as those in the EBAY) were not located near 2 accessible monuments. To measure these sensors, we had to setup additional monuments, marked "PEM" and with the x, y, z coordinate of the monument. These monuments were once again established using bilateration from 2 known monuments.

3.3 Measurements

We used a laser measuring device to accurately measure distances. We used a bob attached to a string to mark the position on the floor directly below the sensor. A block was positioned at this point and we set up the laser measuring device at the monuments and measured the distance to the block. After measuring the distance, we used a bilateration script we developed in order to calculate the x and y coordinates of the sensor. To measure the z coordinate, we simply measured the length of the string needed to reach from the sensor to the ground.