Monitoring Magnetic Fields for Advanced LIGO

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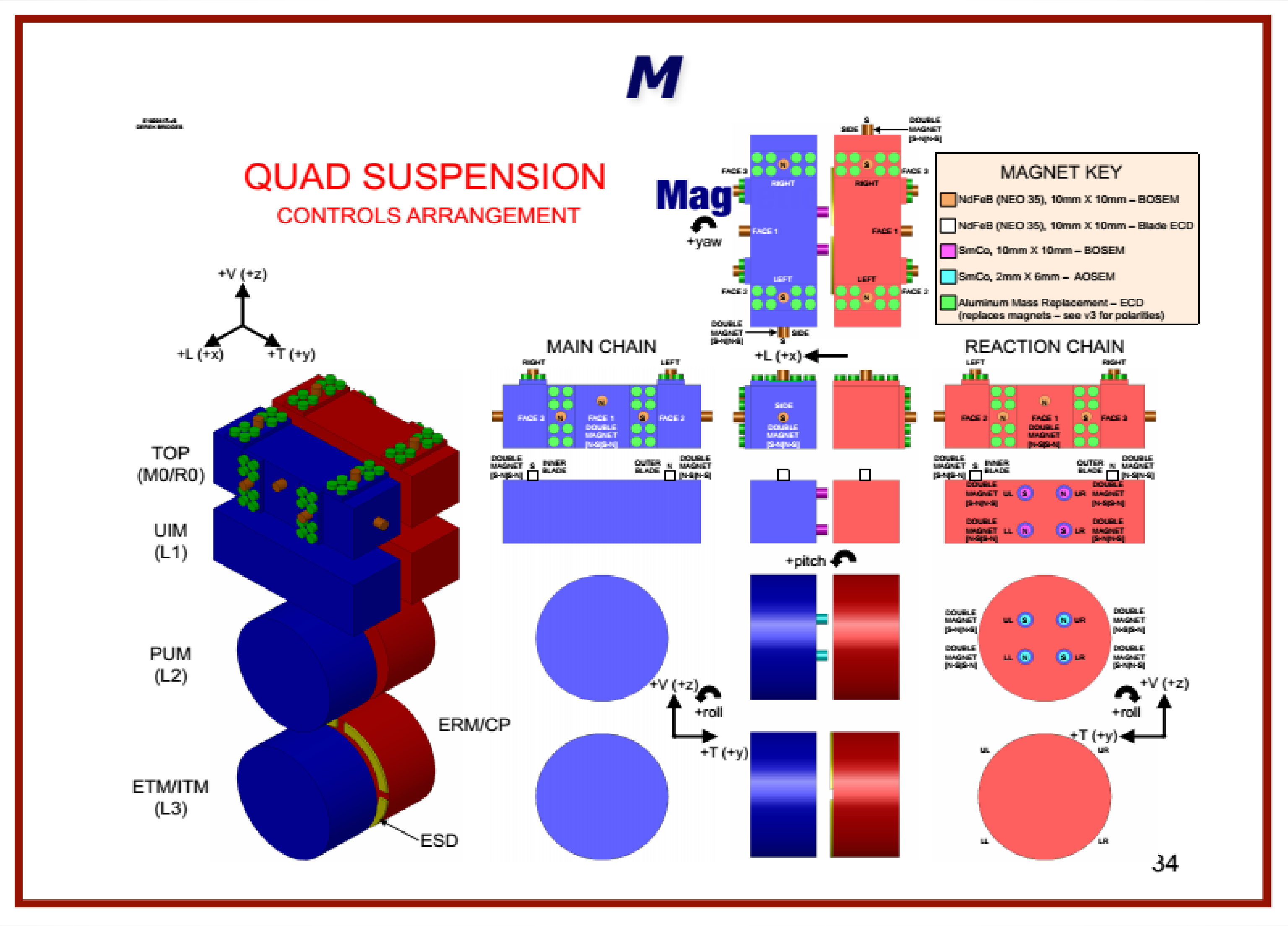
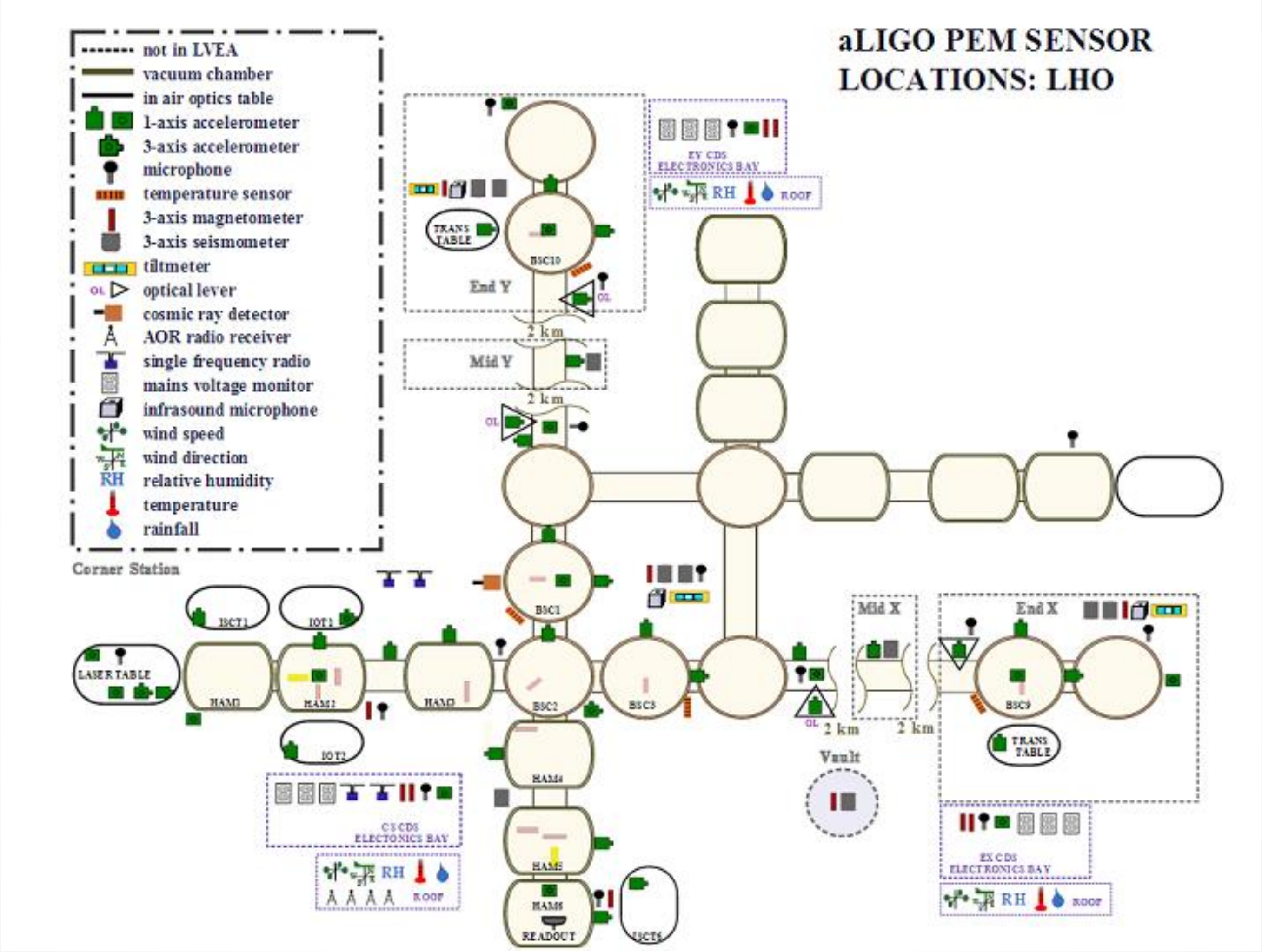
LIGO Hanford Observatory

How can ambient magnetic fields affect Advanced LIGO?



Physical Environment Monitoring (PEM) Map
LIGO Hanford Observatory



Magnetometer Data Acquisition System

Magnetometer

Analog

Signal Conditioning Box

Analog

Filter Box

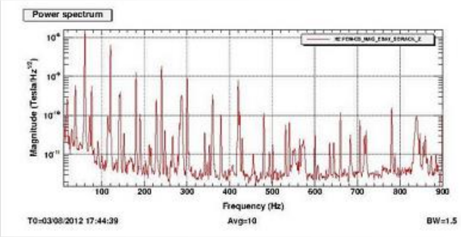
Analog

Anti-Aliasing Chassis

Analog

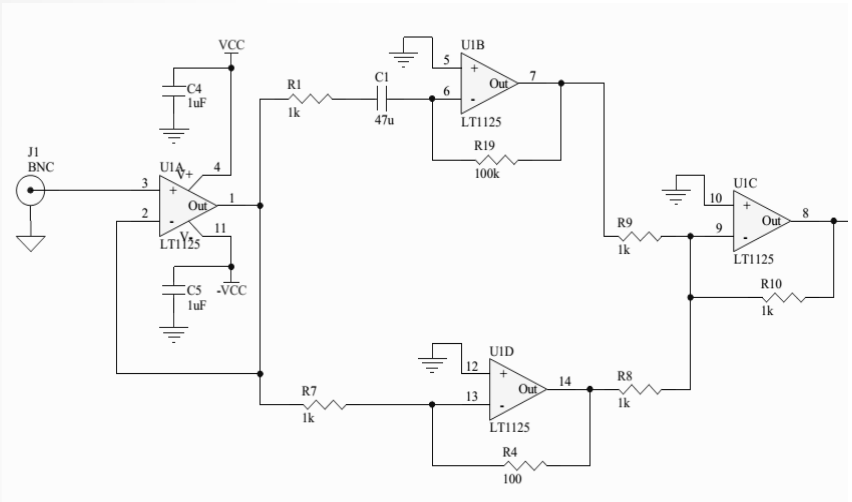
Analog Digital Converter

Digital

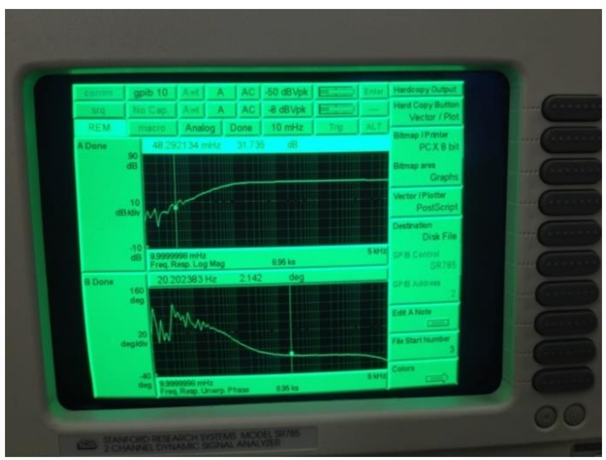


Power Spectra from Diagnostic Test Tools [LIGO software]

Filter Box Modification

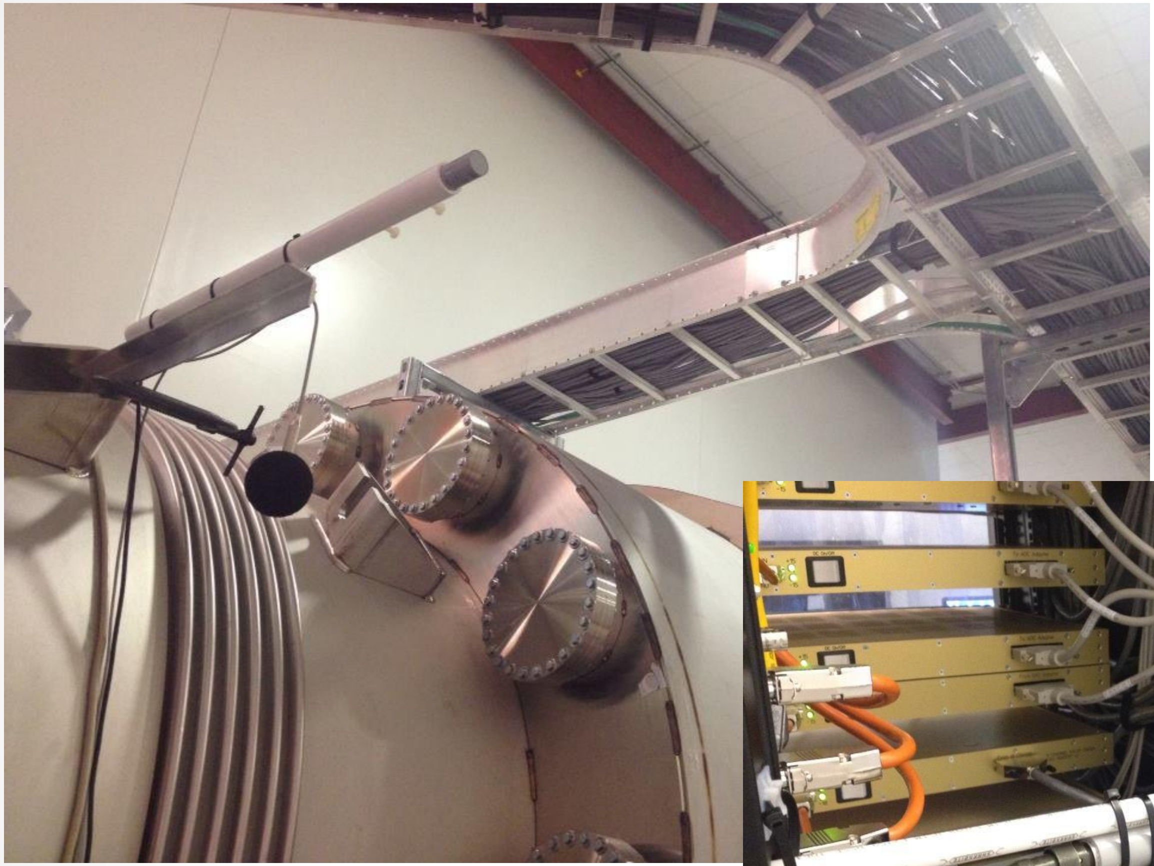


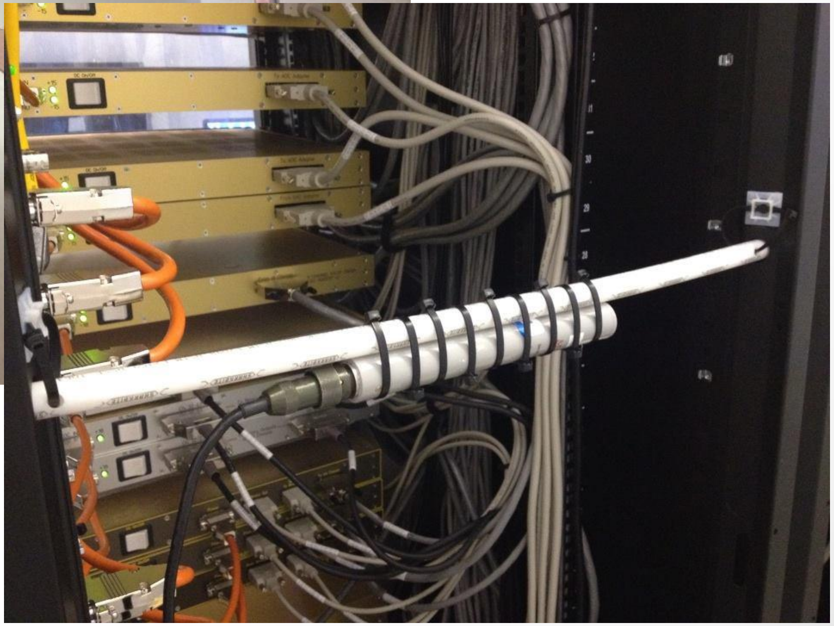
$$f = \frac{1}{wRC}$$



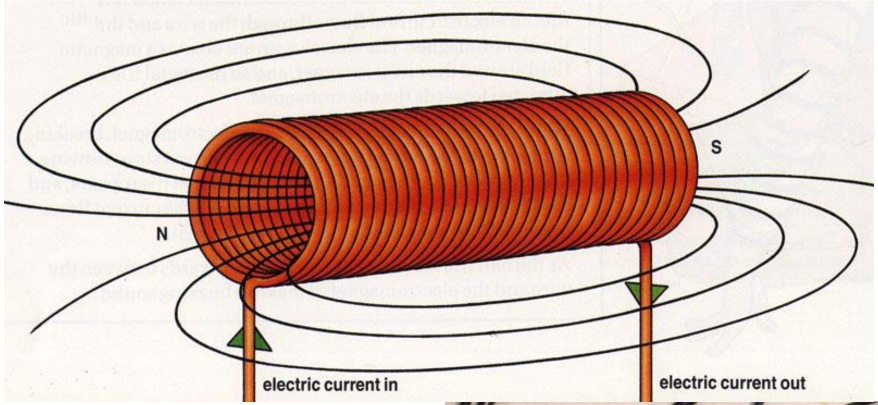
$$Gain = \frac{R_1}{R_2}$$

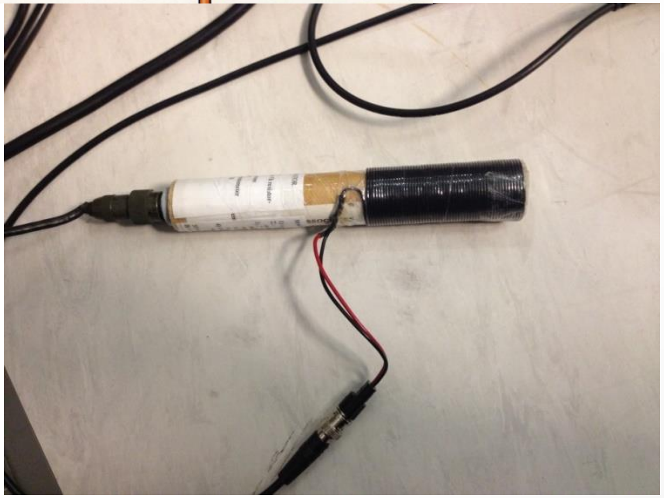
Magnetometer Installation – LVEA and End Y Electronics Bay





Magnetometer Calibration





$$\oint \vec{B} \cdot d\vec{l} = \mu_o I_{enc}$$

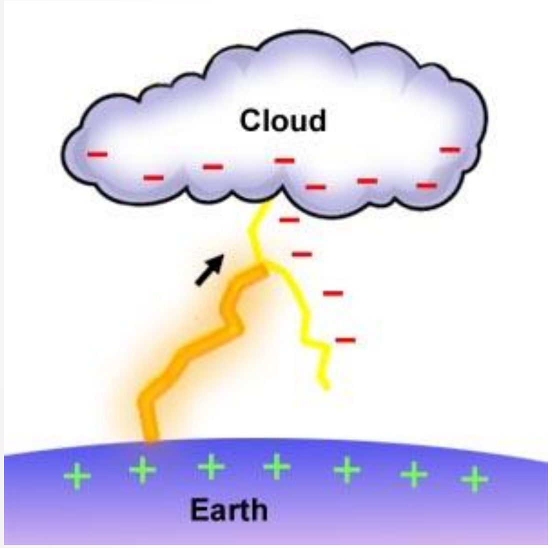
$$B = \mu_0 \frac{N}{l} I$$

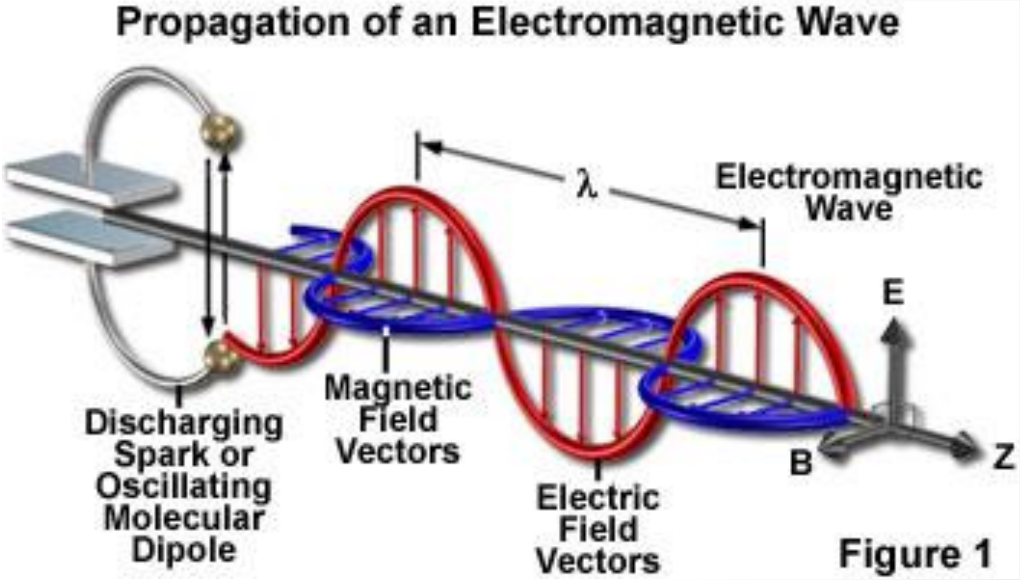
What about other magnetic fields?

- So far, we have considered site-specific fields
- But certain “global” magnetic fields can act like gravitational waves passing through both sites
- Lower the Advanced LIGO noise floor by subtracting these fields from the gravitational wave channel for the stochastic gravitational wave search
    - Geomagnetic Field Observatory possibility

Source of Schumann Resonances: Lightening

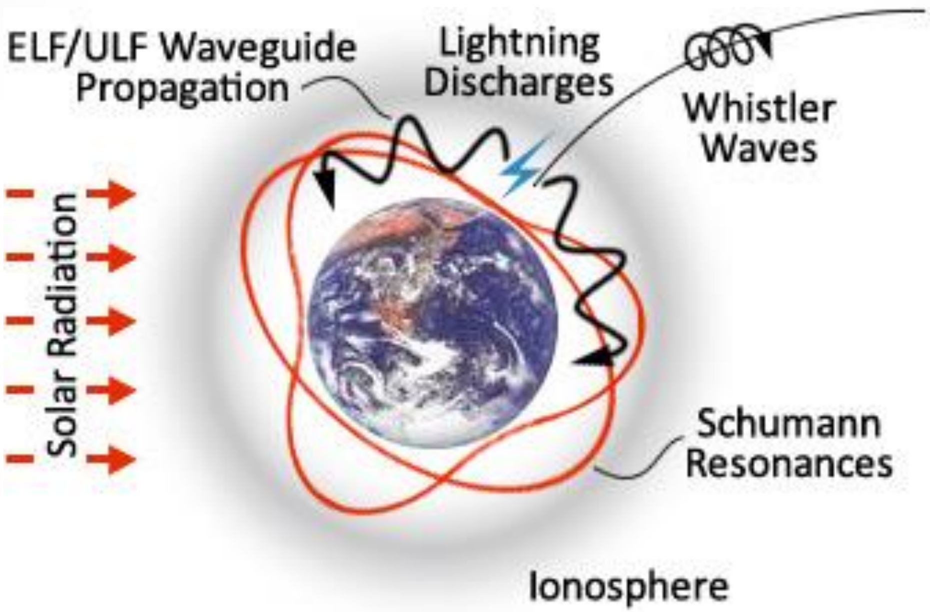
- Lightening, an electrostatic discharge





- Sudden discharge produces an electromagnetic wave

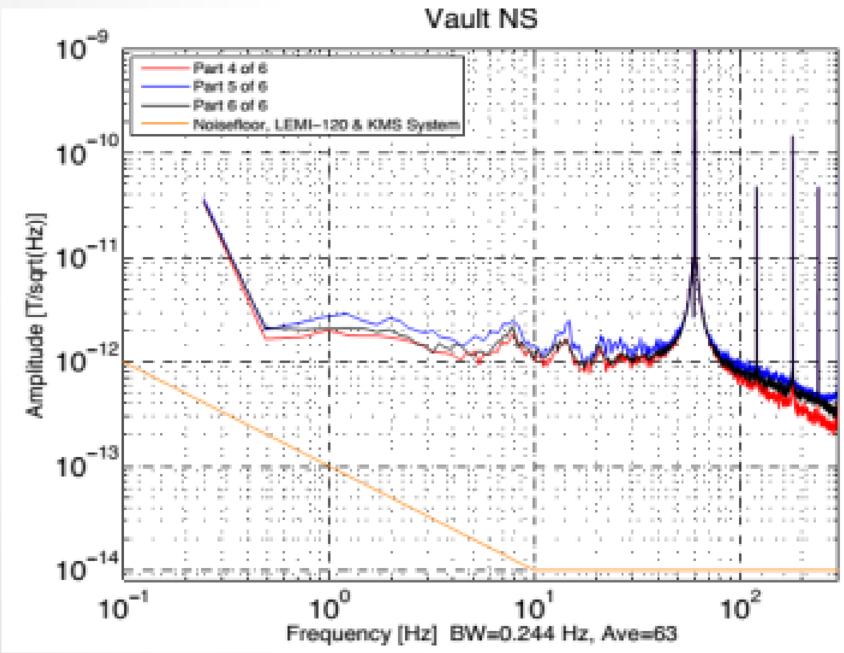
Schumann Resonances (Continued)

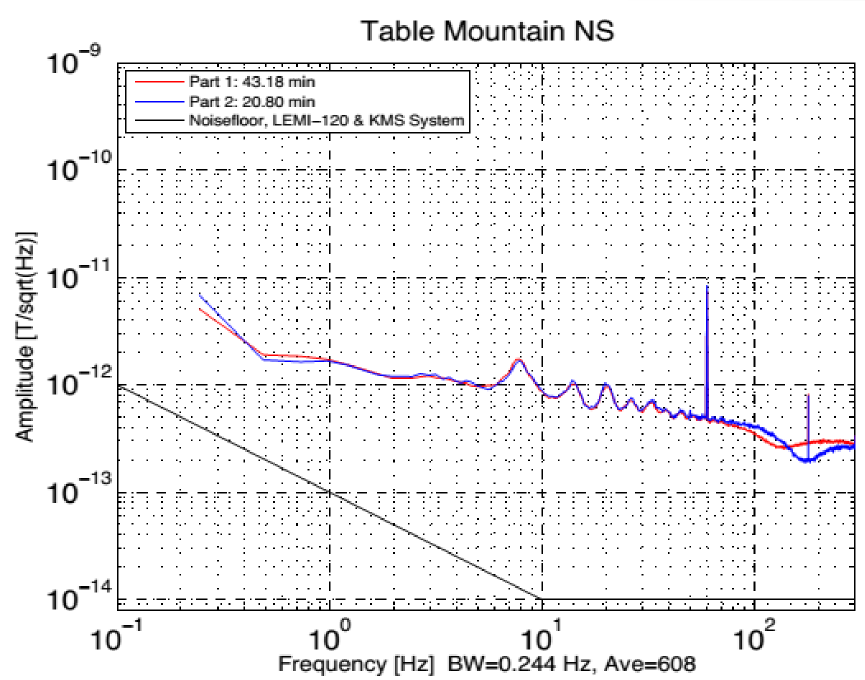


- An electromagnetic wave from a lightening strike propagates spherically, resonating between the ionosphere and the Earth's surface
- Resonant frequencies: 7.8 Hz (fundamental), 14.3 Hz, 20.8 Hz, … , 60 Hz
- Light travels around the world in 1/8th of a second

Comparing the Sites

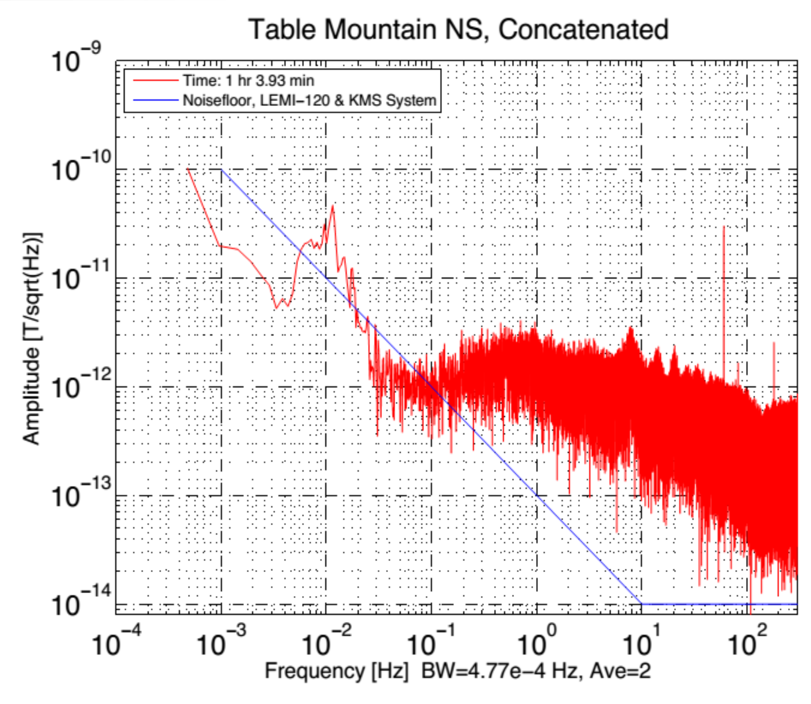
- 60 Hz peak gets smaller with magnetic isolation
- Schumann Resonances not covered up in Table Mountain plot

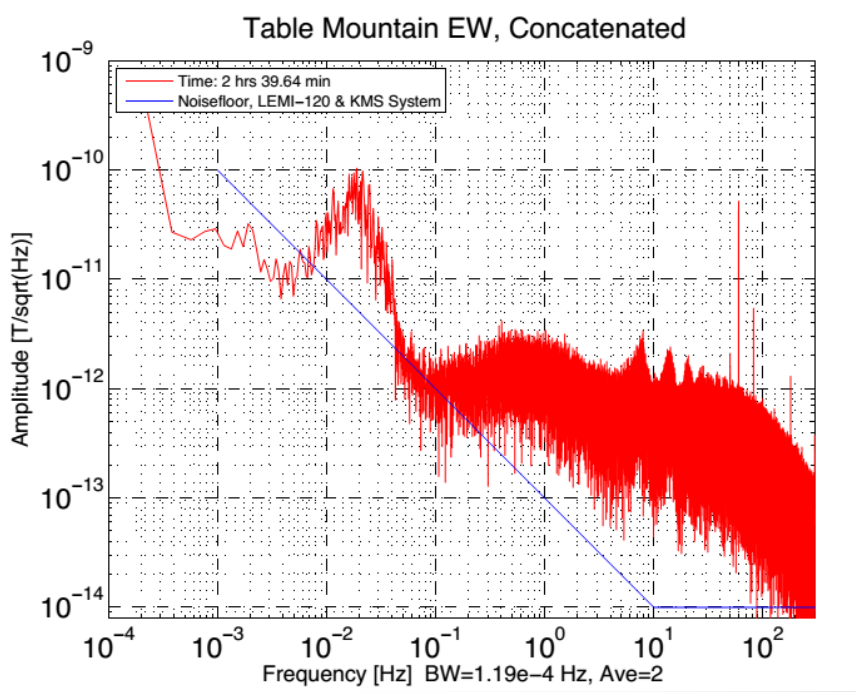




Viewing the Same Data in a Different Way

- Ultra Low Frequency (ULF) wave: 1mHz – 1Hz
- 0.01 Hz Resonance – pc4 frequency band within ULF range

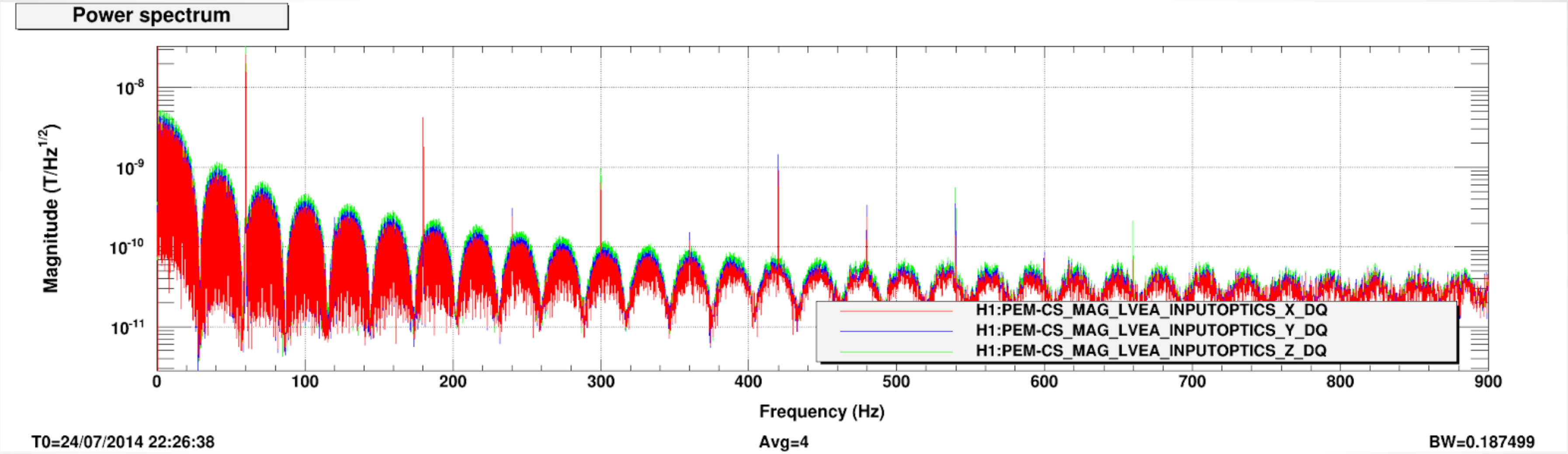


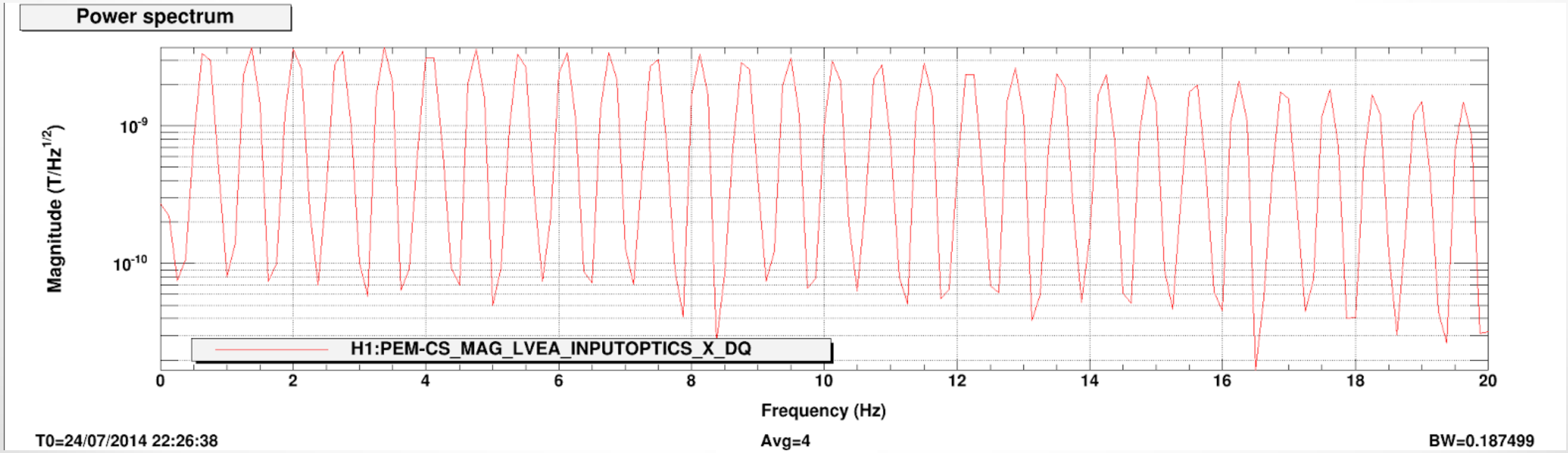


How close can electronic devices be to the interferometer?

- Uninterruptible Power Supply (UPS) for the Pre-Stabilized Laser (PSL)
- Lights simulate load from pre-stabilized laser
- Set-up variables
  1. Angle
  2. Distance
  3. On/off configurations

First power spectra

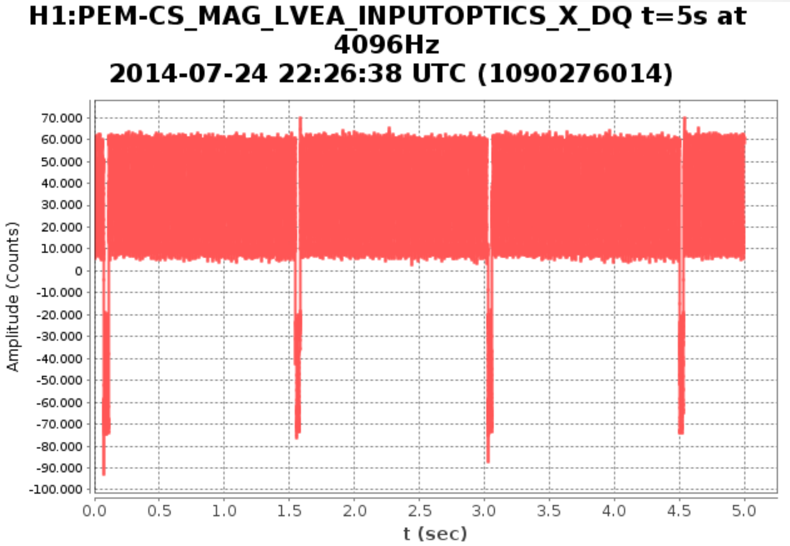


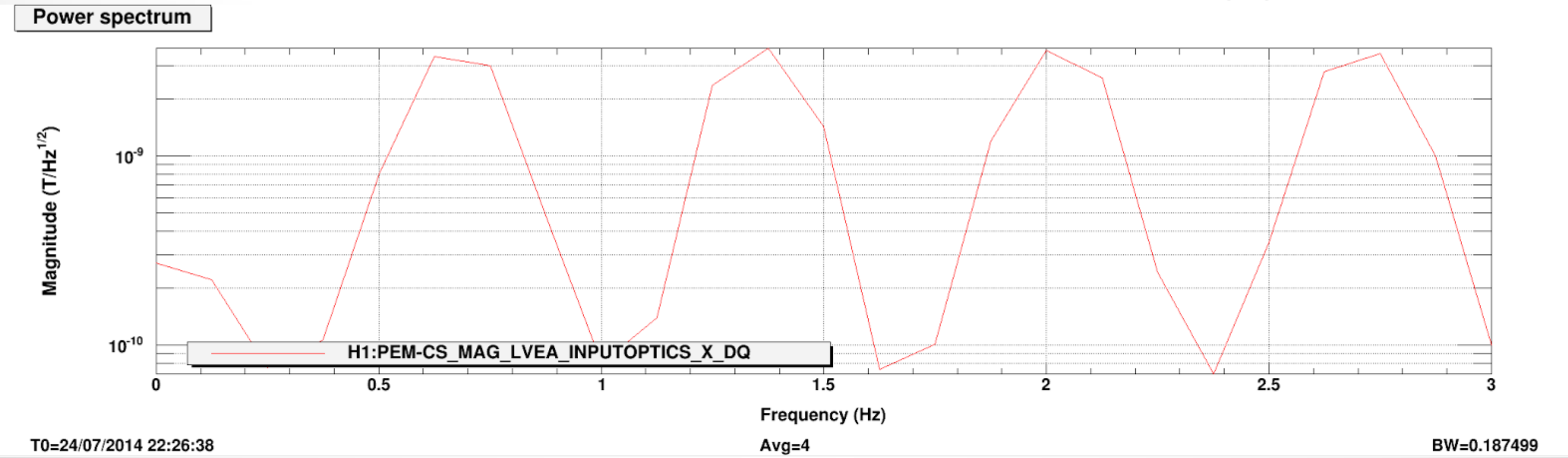


Fourier Analysis - 1

- Time (T) between glitches: 1.5 seconds

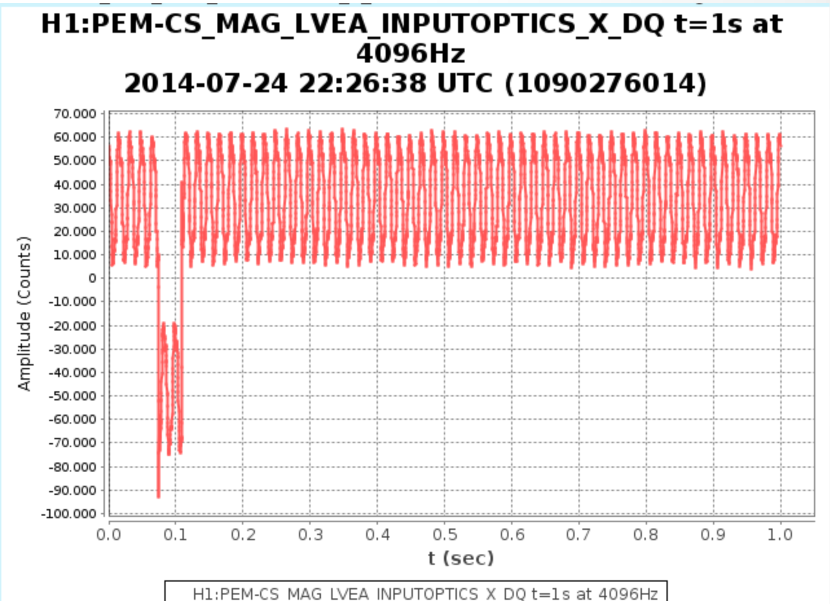
- $f = \frac{1}{T} = \frac{1}{1.5} = .67$ Hz

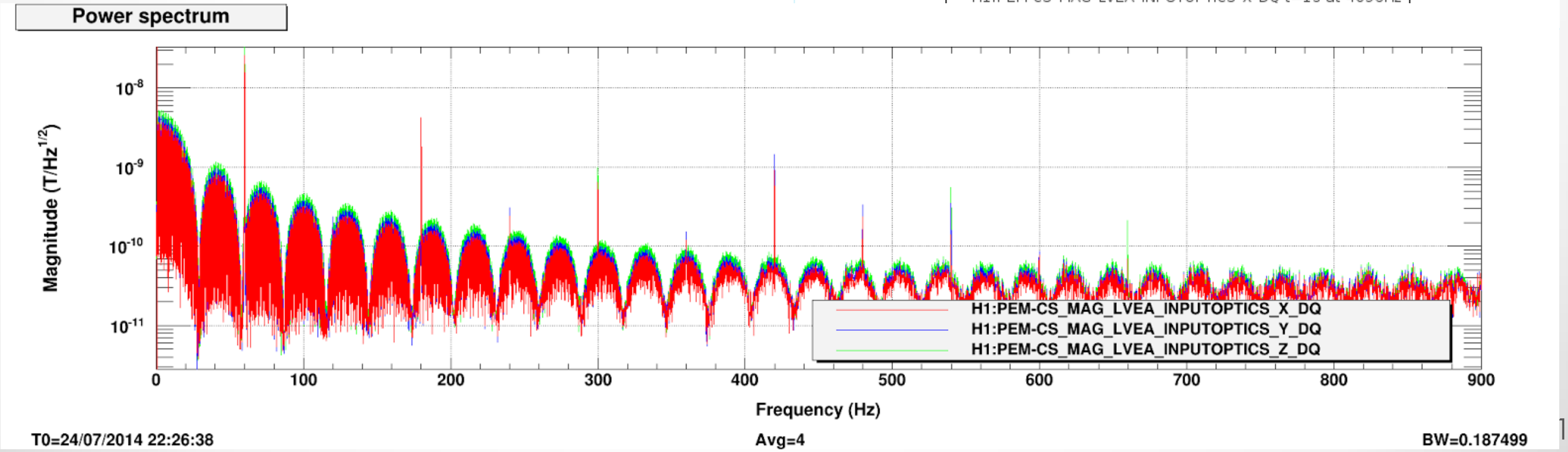




Fourier Analysis - 2

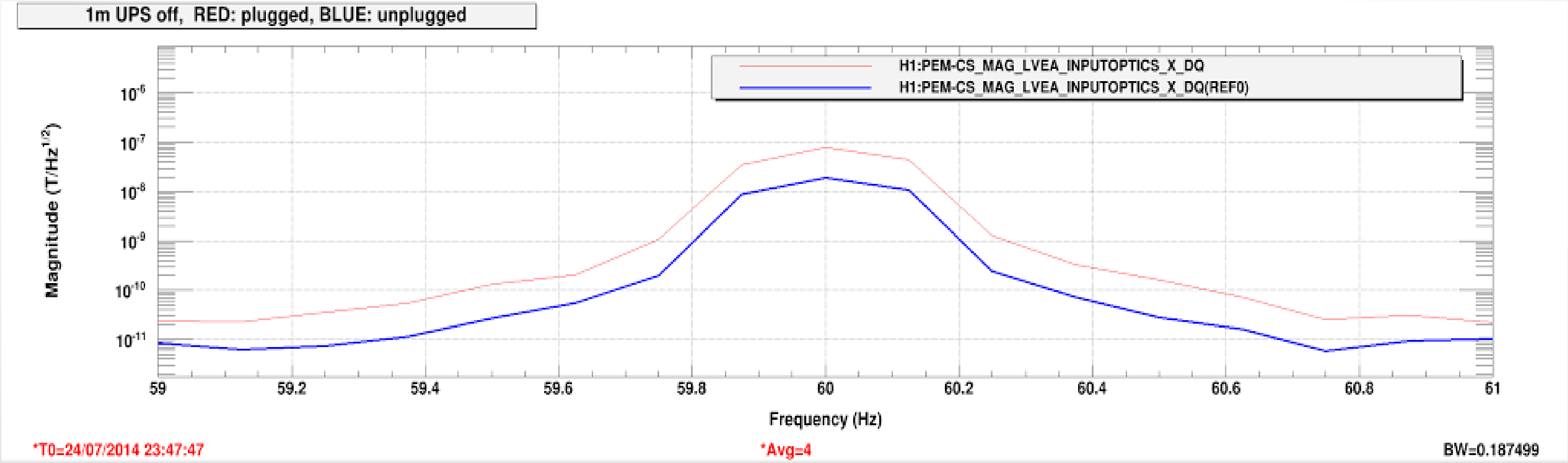
- Time (T) of glitch: .04 seconds
- $f = \frac{1}{T} = \frac{1}{.04} = 25\text{ Hz}$





Magnetic field from UPS system

- 1m
- 90°
- Off & plugged vs. off & unplugged
- Our spec for 60 Hz peak is .5 nT – one tenth of the average field during old science runs

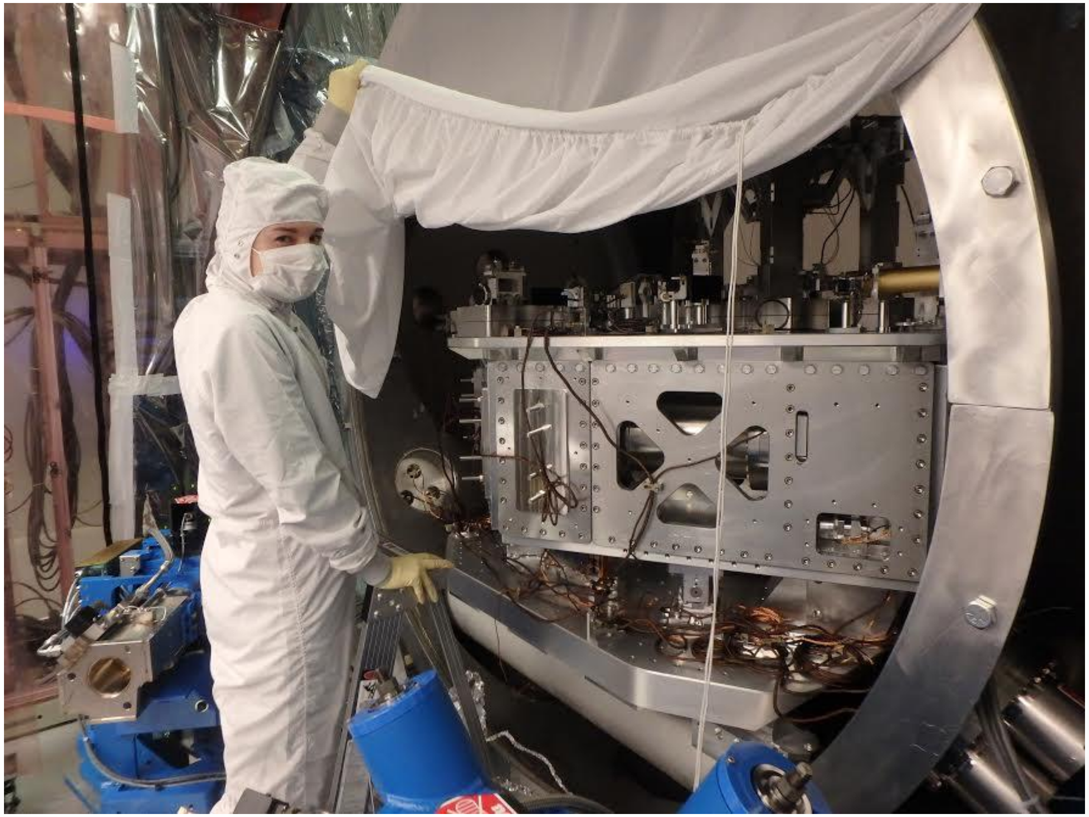


Future Work

1. Magnetometers
    1. Custom magnetometer mounts
    2. DC power to signal conditioning boxes
    3. Filter box modifications + check transfer functions
    4. Cabling
    5. Calibration
2. UPS system
    1. Improve measurement of attenuation of magnetic field with distance
3. Investigate magnetic coupling to:
    1. Seismometer
    2. Gravitational wave channel (if interferometer is active)

Thank you…

…for a rewarding and exciting summer at LIGO!



Acknowledgements

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LIGO SURF Program