Schumann resonances exploration with external data

Michael Coughlin, Nelson Christensen

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Introduction

1. There are potential environmental noise sources correlated between spatially separated detectors, such as Schumann resonances
2. These correlations will possibly begin to contaminate the gravitational-wave data streams and thus the detection of the stochastic gravitational-wave background.
3. Correlated noise produces a system error that cannot be reduced by integration, and therefore is a fundamental limit for SGWB searches.

Schumann Resonances

1. Schumann resonances are due to the waveguide features formed by the highly conducting Earth and ionosphere.
2. They are excited by a background of about 100 lightning strikes per second with 20-30 kA of current and lengths of 3.5 km.
3. These resonances produce magnetic fields on the Earth's surface of 0.5-1.0 $\mathrm{pT/Hz^{1/2}}$, with 10 pT bursts appearing above a 1 pT background at a rate of 0.5 Hz.
4. By requiring that the resonance wavelengths be an integer fraction of the circumference of the Earth, Schumann showed that the resonant frequencies are approximately

$$f_n = 6.0\sqrt{n(n+1)}(Hz) \tag{1}$$

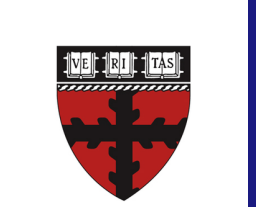
From this, it is clear that the primary peak is at 8Hz with secondary and tertiary harmonics at 14Hz and 20Hz respectively, and the peaks have a spectral width of 20% and vary seasonally and with proximity to lightning storms.

Data Quality

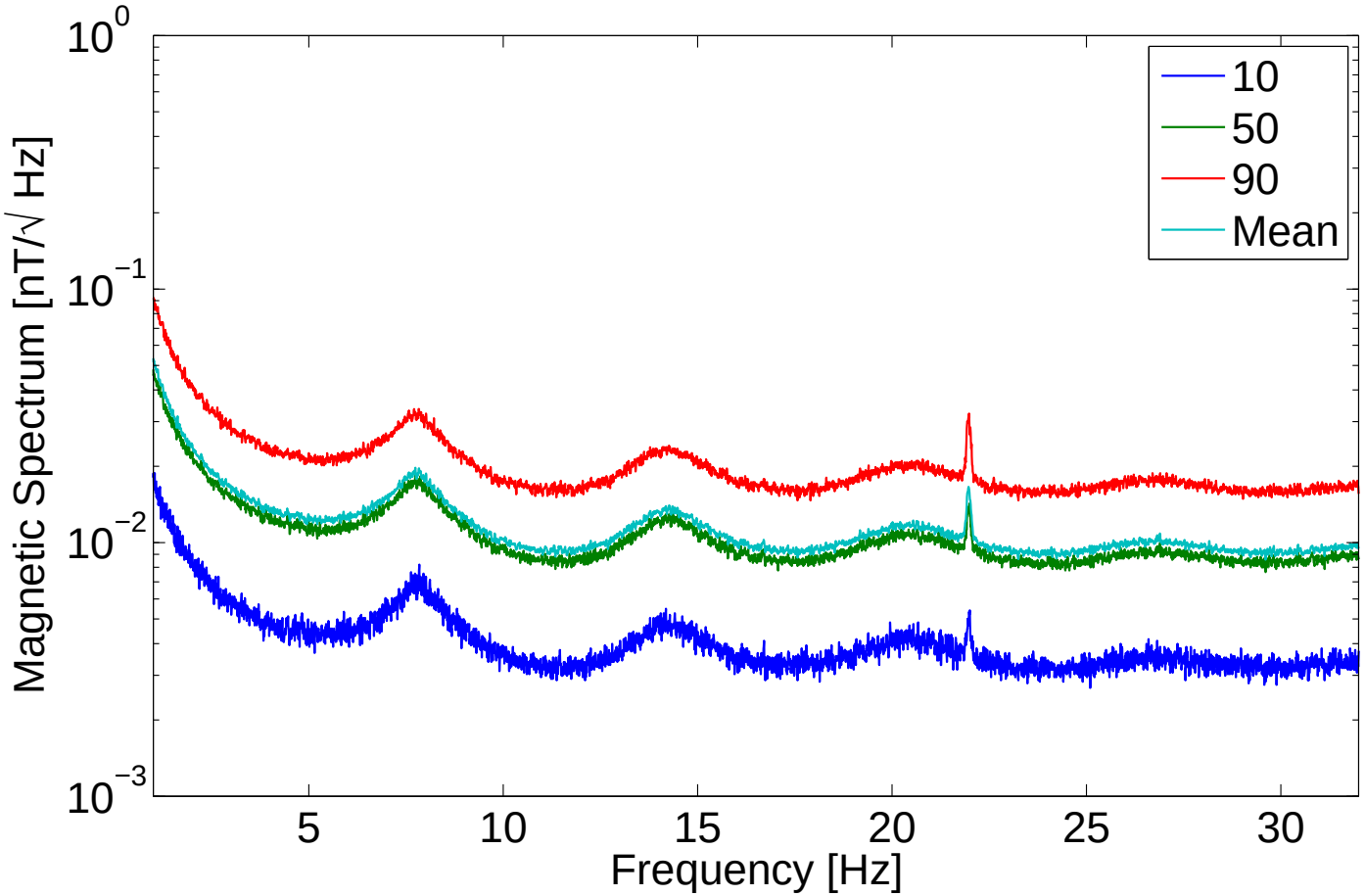
1. We will show below that the local magnetic field can at times dominate the spectrum.
2. In Irene's analysis, she uses an RMS based data quality cut.
3. In our analysis, we instead use the seismic method of using all data but producing percentile based PSDs and Coherences, which are less effected by transients.

ELF magnetometer stations

1. 2 Extremely Low Frequency magnetometer stations, 1 Poland and 1 Colorado
2. Each with 2 channels

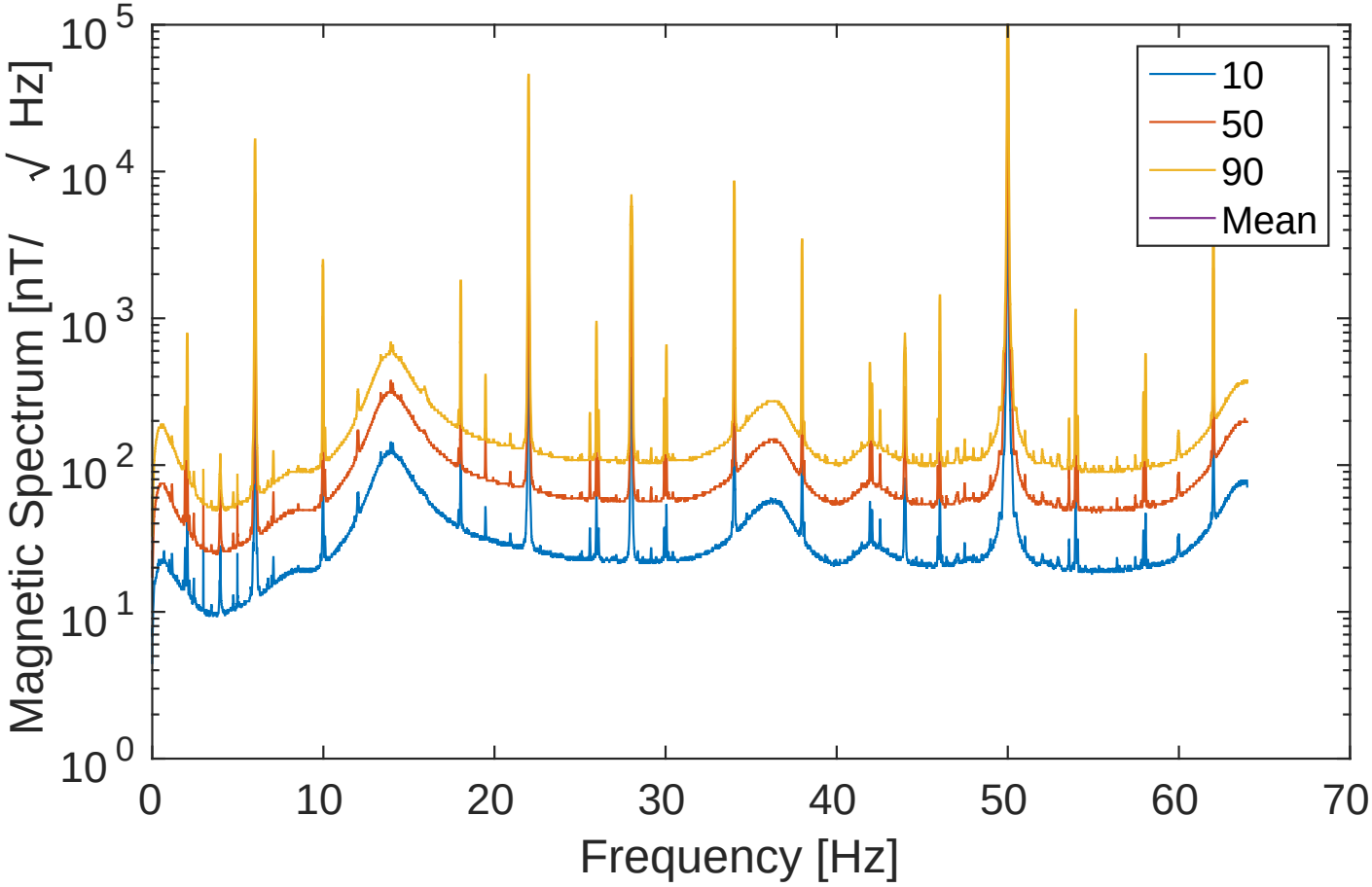


PSDs

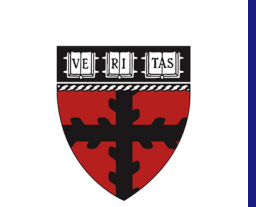

10^0
10^{-1}
10^{-2}
10^{-3}
Magnetic Spectrum [nT/√ Hz]
5
10
15
20
25
30
Frequency [Hz]
10
50
90
Mean

(a) PSD

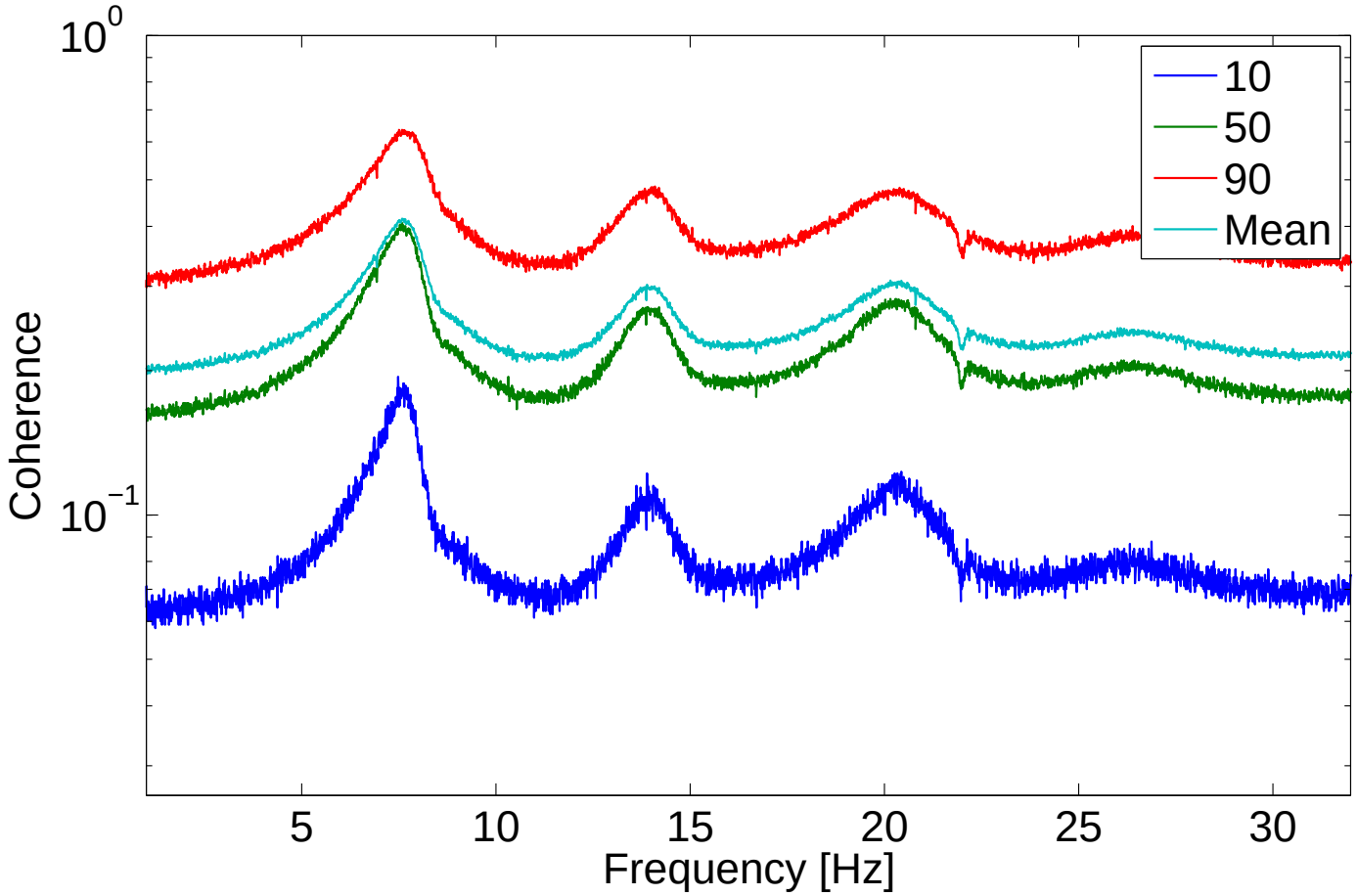
PSDs (Virgo)



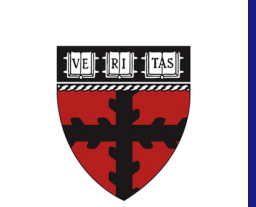
(b) PSD



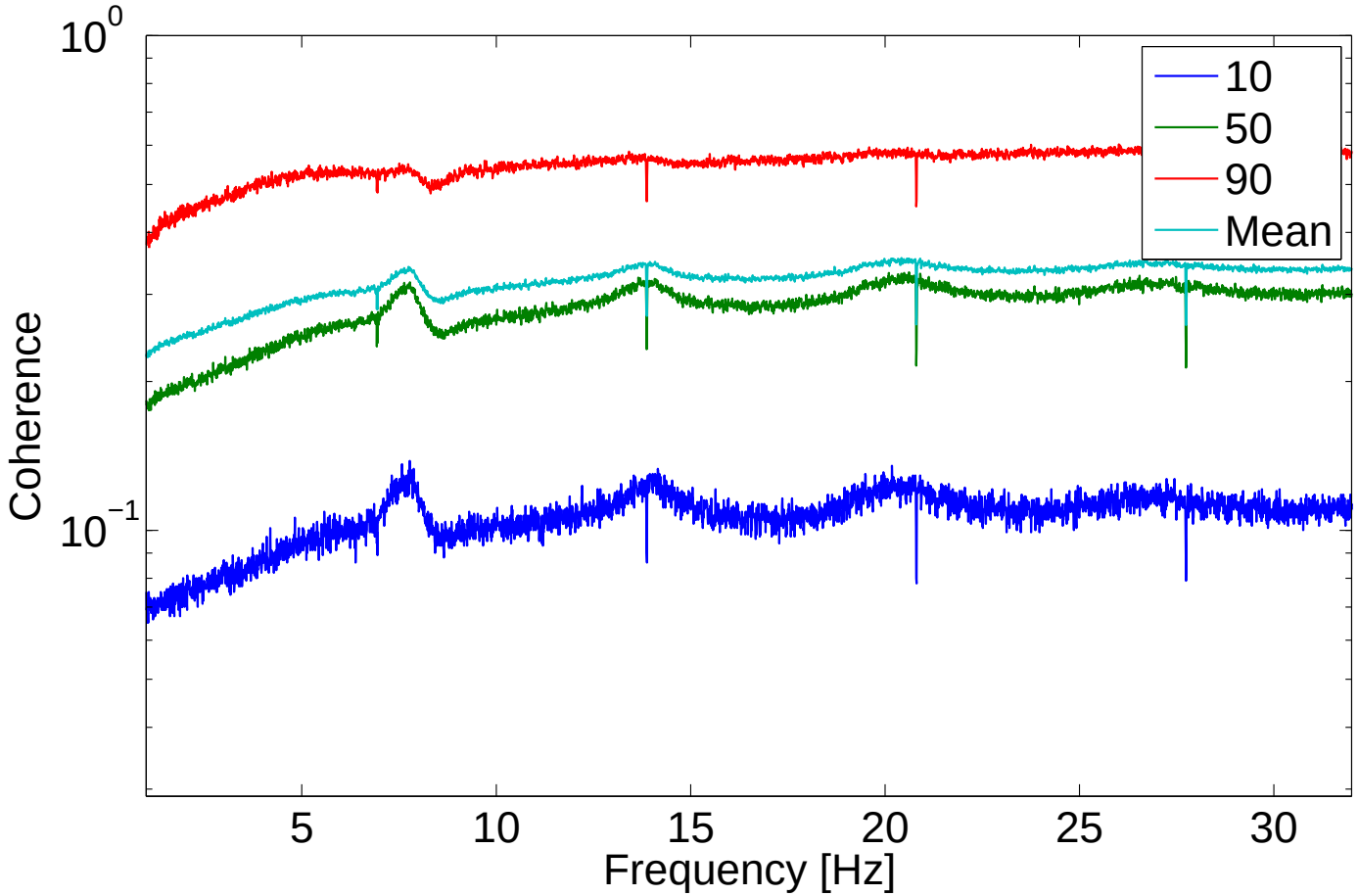
Coherences: POL and COL



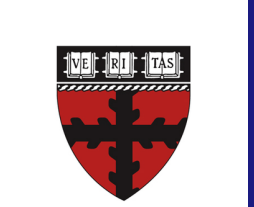
(c) COH



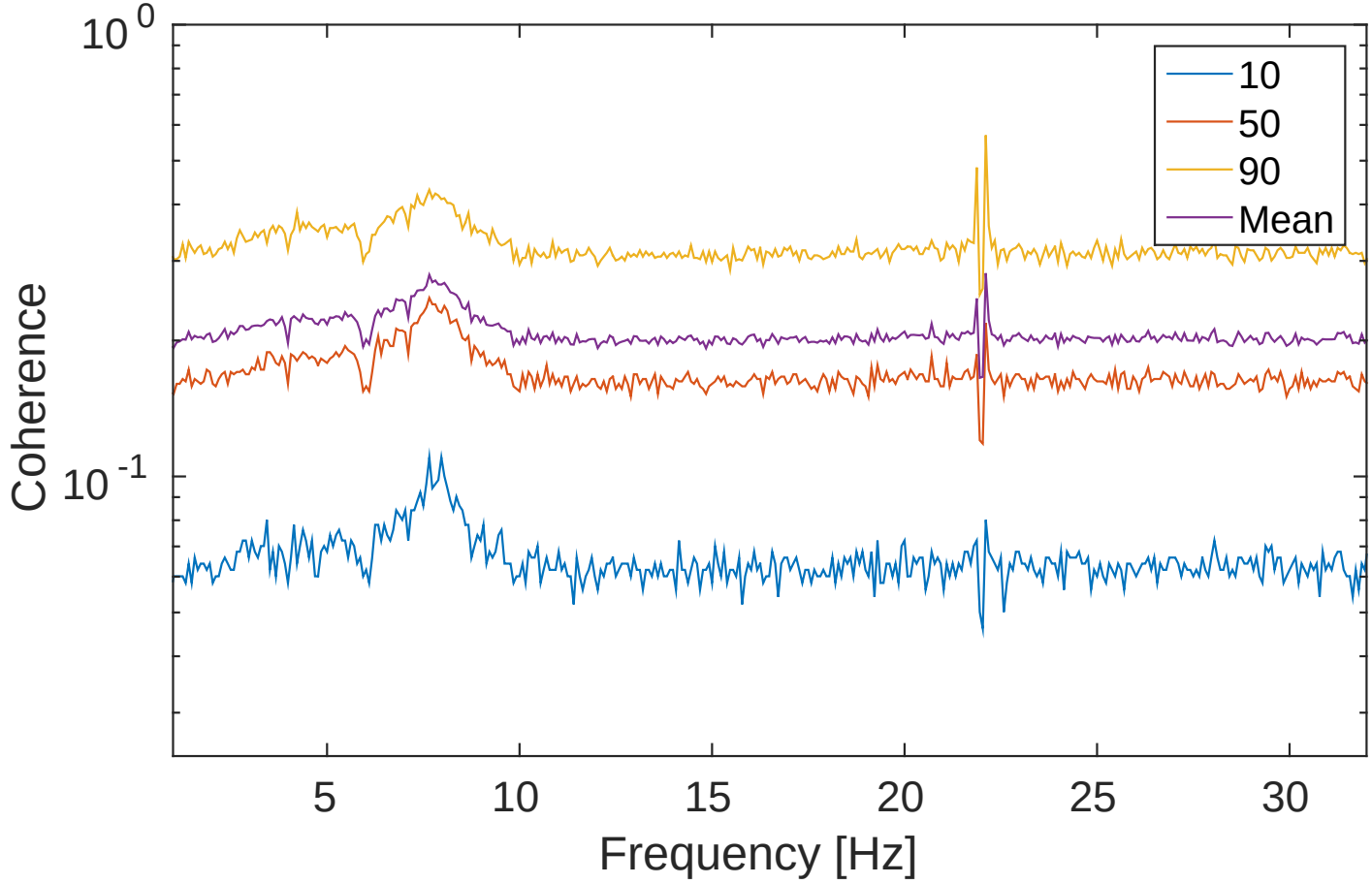
Coherences: POL1 and POL2



(d) COH

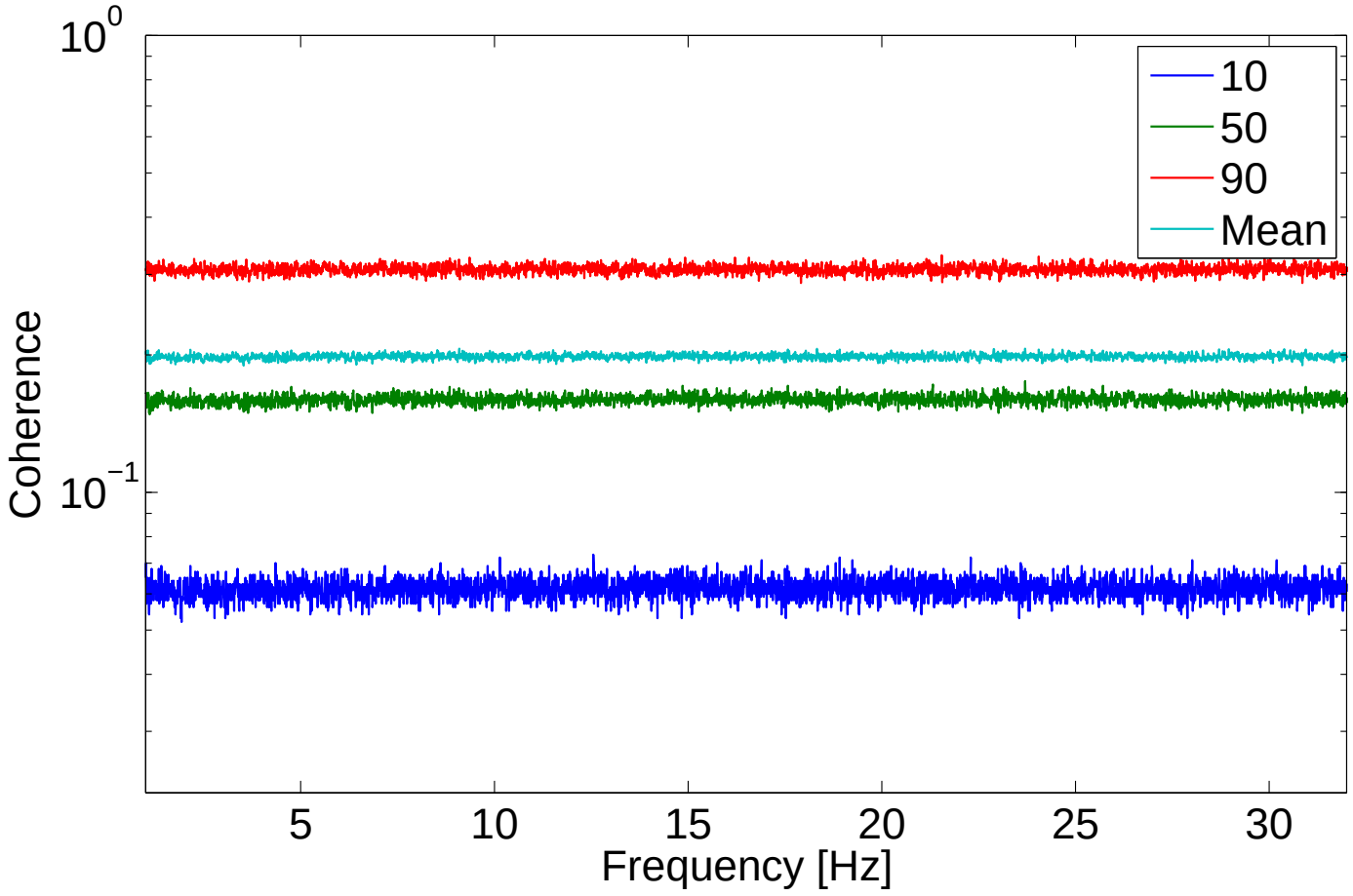


Coherences: POL and Virgo



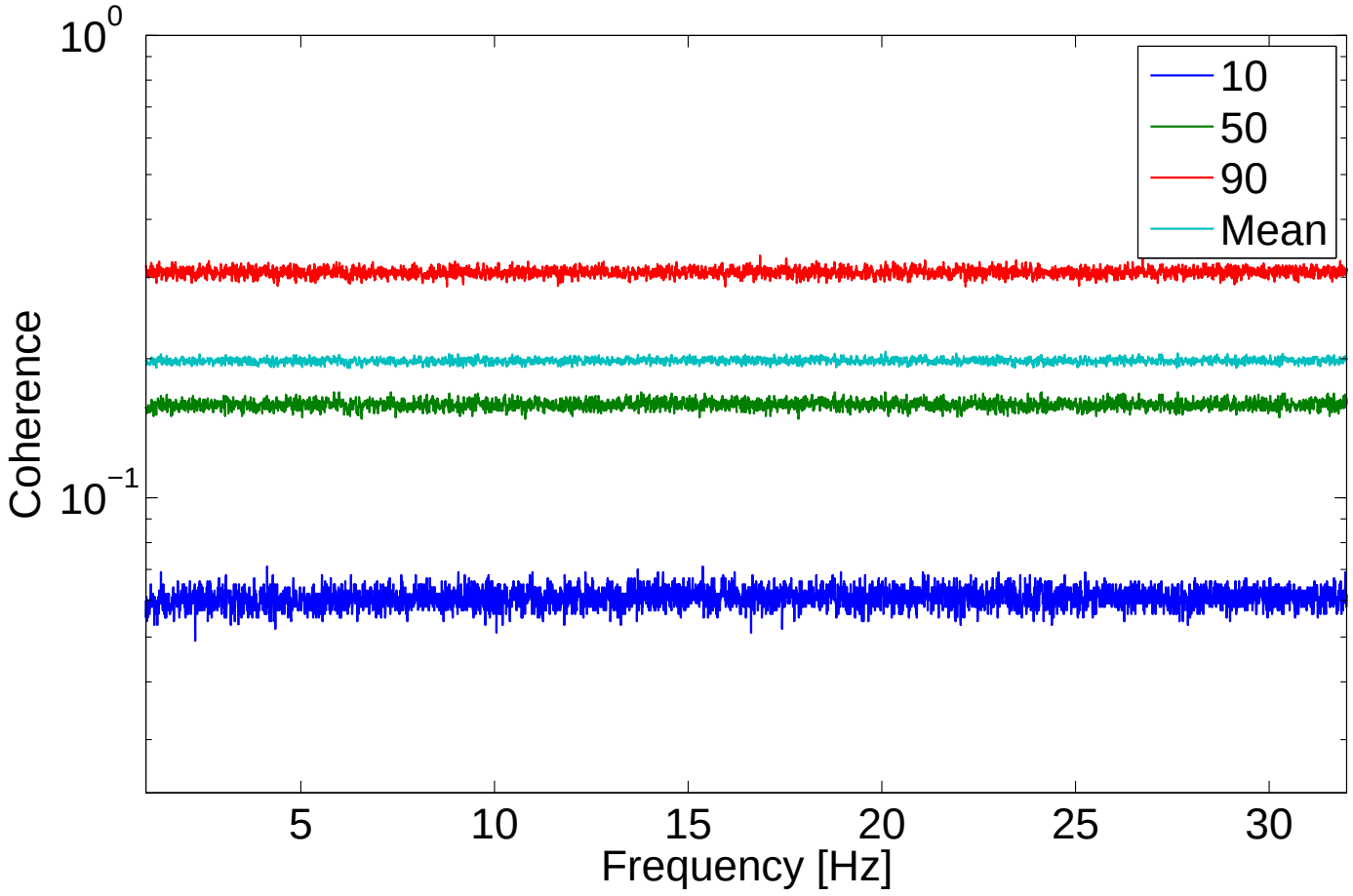
(e) COH

Coherences: POL and H1 Mag

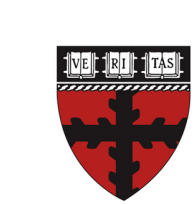


(f) COH

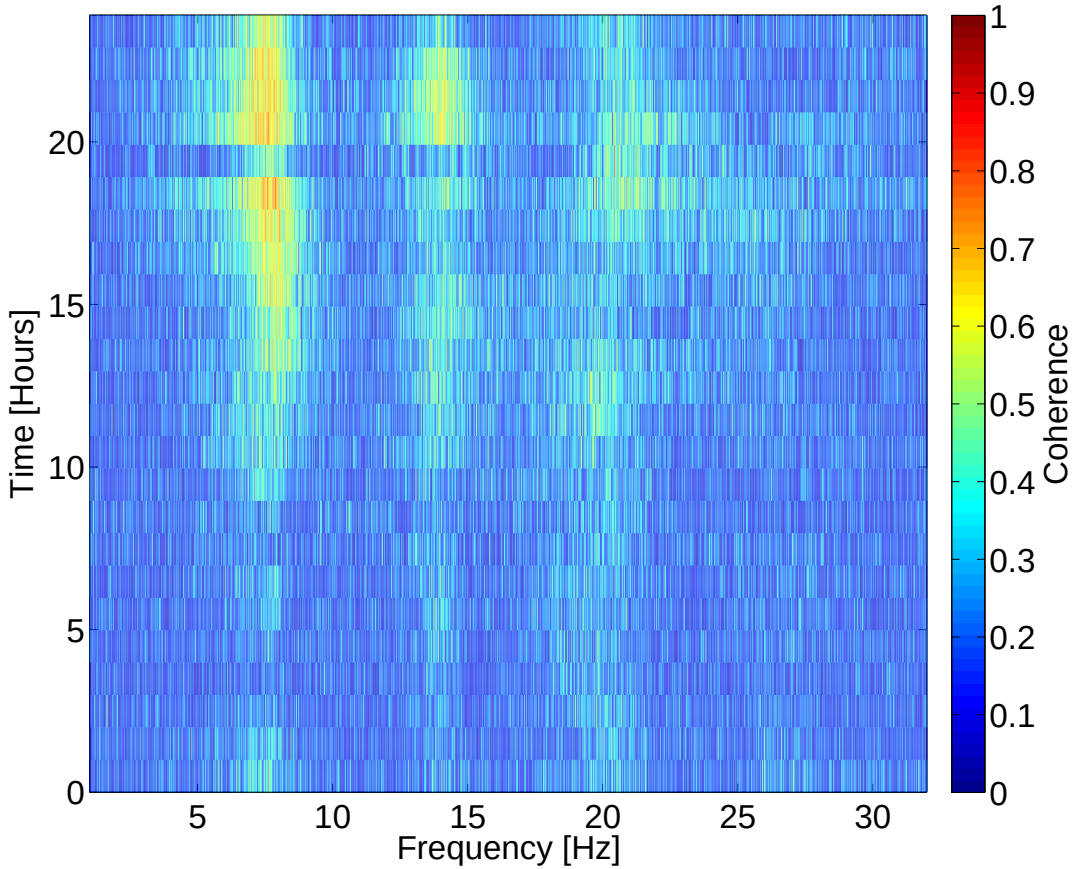
Coherences: POL and H1 h(t)



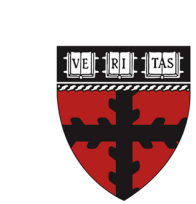
(g) COH



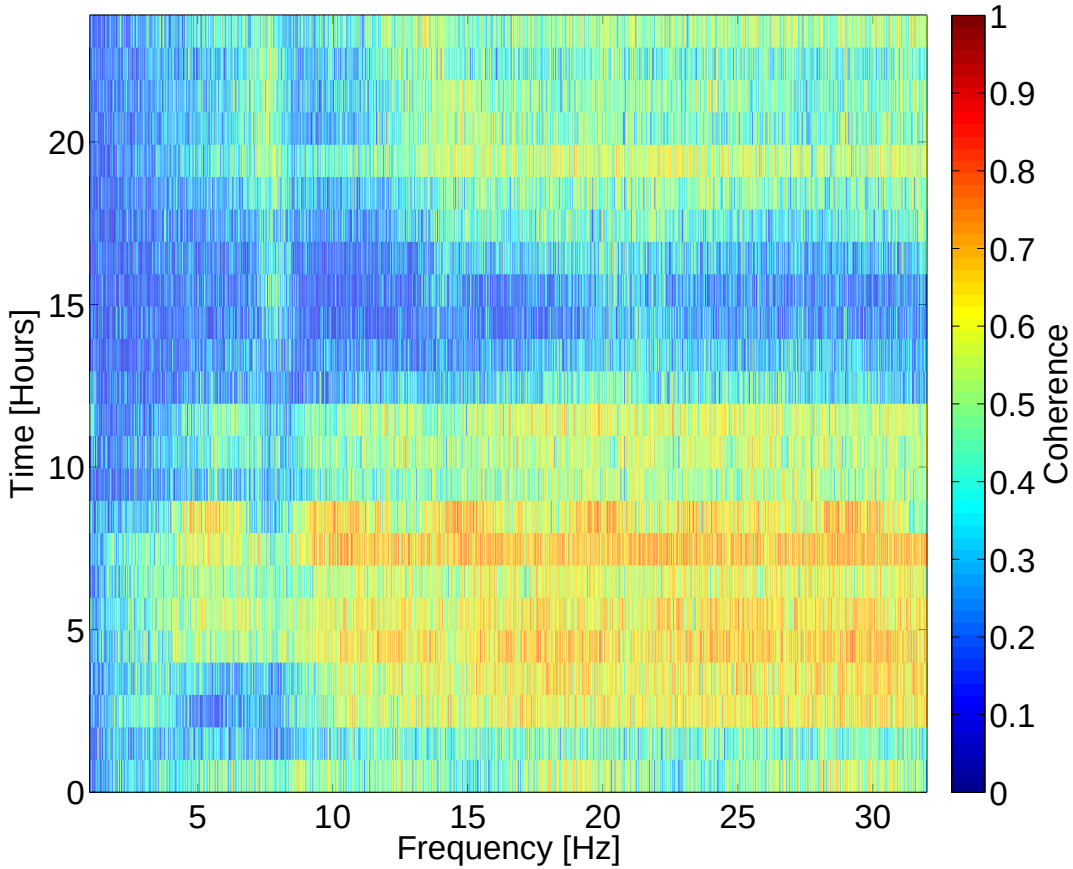
Coherence Time-frequency



(h) COH

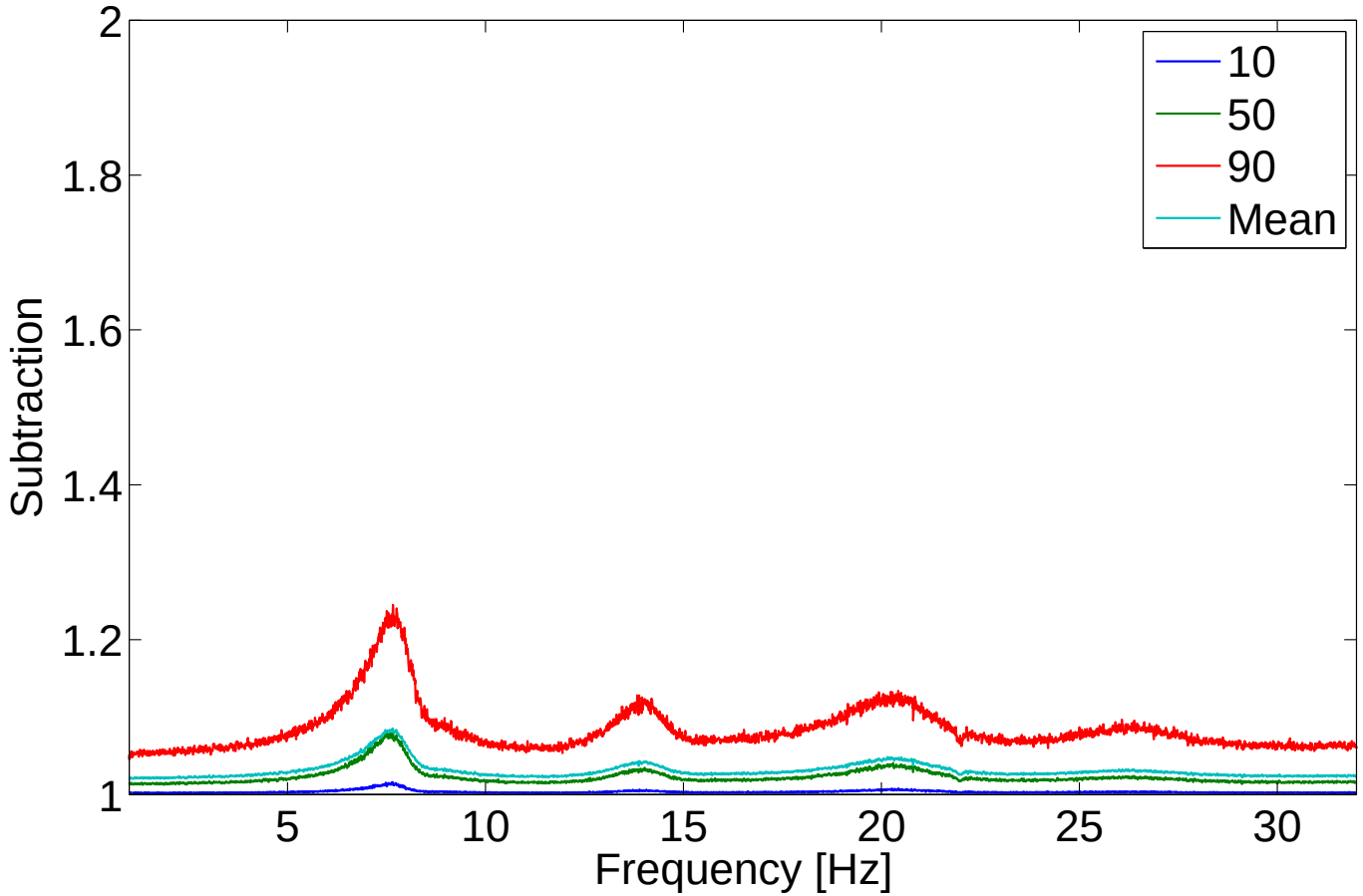


Coherence Time-frequency: Colocated



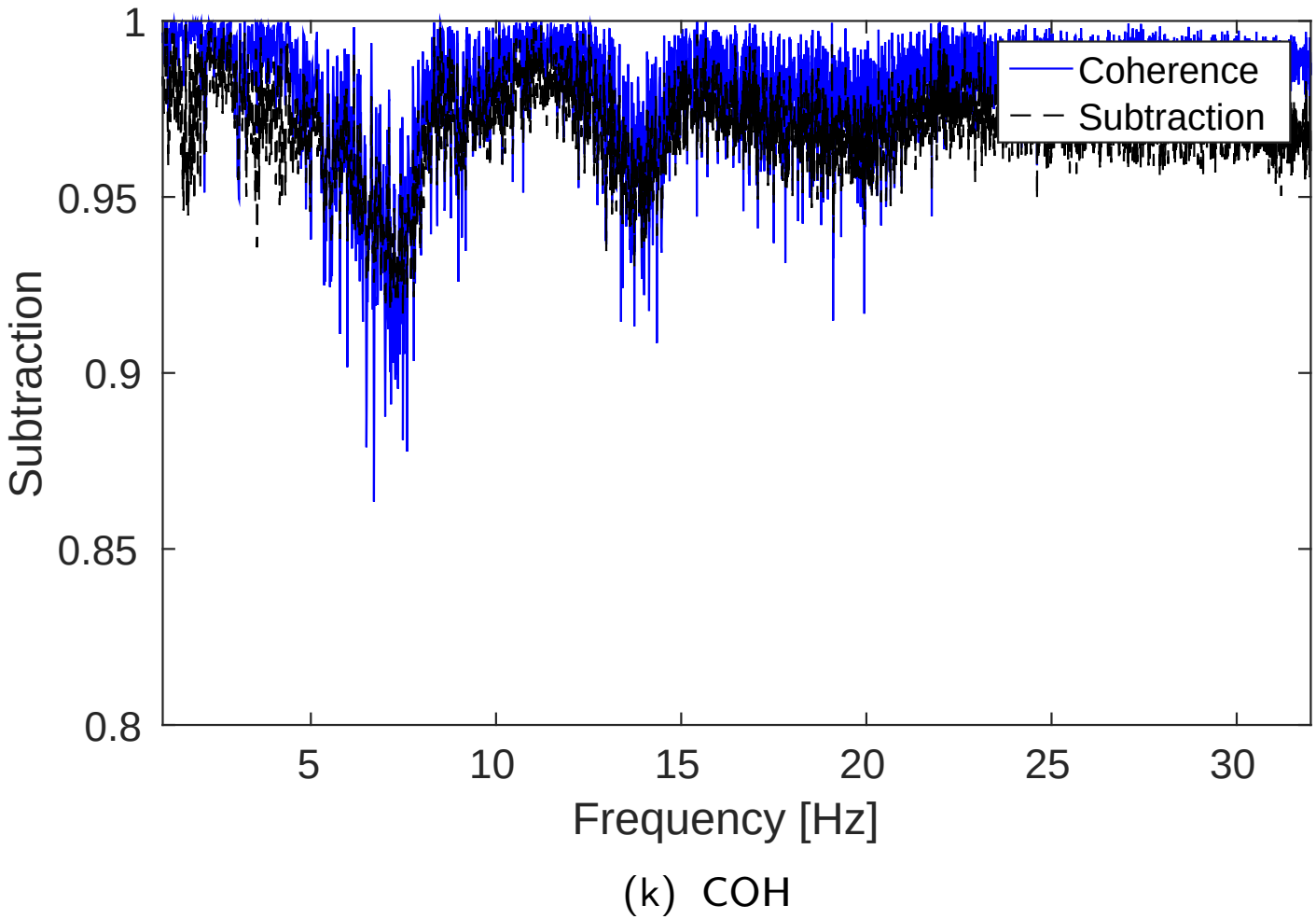
(i) COH

Theoretical Subtraction



(j) COH

Subtraction Example



(k) COH

Conclusions

1. We can clearly see Schumann resonances in these magnetometers.
2. Seeing those same resonances is very difficult with the magnetometers on site (and potentially the strain channel).
3. We will want a ELF magneometer at each site due to local disturbances interrupting local coherence.
4. These will be necessary to do subtraction on the sites (coherence not high enough otherwise)