ILC2008

RTML and stray magnetic fields.

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Previous work 1

- Sensitivity to Nano-Tesla Scale Stray Magnetic Fields, by **J. Frisch, T. O. Raubenheimer, P. Tenenbaum,** SLAC, LCC-Note-0140 (June 7, 2004)
  - Analysis for NLC
  - Data from SLC (End station B)
  - Conclusion: *we are mostly OK*
  - **Questions:**
    - **How representative is the data?**

Previous work 2

- Rough estimation of effects of fast changing stray field in long transport of RTML - Emittance dilution in Turnaround, **K. Kubo,** KEK, ILC-Asia-2006-05 October 12, 2006
  - Requirement estimation: rms B < 2 nano-Tesla (ILC RDR), relaxed to 10 nanotesla (1e-4 Gauss).

Magnetic fields

- Commercial superconducting solenoid – **10 Tesla (1 e+1)**
- Earth magnetic field -- **50 micro-Tesla (5 e-5)**
- Cell phone – **100 nano-Tesla (1 e-7)**
- ILC-RDR requirement – **10 nano-Tesla (1 e-8)**
- Beating human heart -- **~ 10 pico-Tesla (1 e-11)**

Classification

Following F.R.T. paper:

- 60 Hz and its harmonics (near-coherent with 5-Hz pulsing)
- Fields from RF systems (coherent with 5-Hz pulsing)
- Others (non-RF technical sources) (uncorrelated with pulses)

Assumptions:

Frequency < 0.1 are compensated by feedback. Higher frequency in uncorrelated noise ~ 1/f^2 (to keep energy density approximately constant). Very high frequencies (>100 kHz) attenuate in the structure.

We will look at ~0.1 Hz < f < ~10 kHz, in particular at 60 Hz problem.

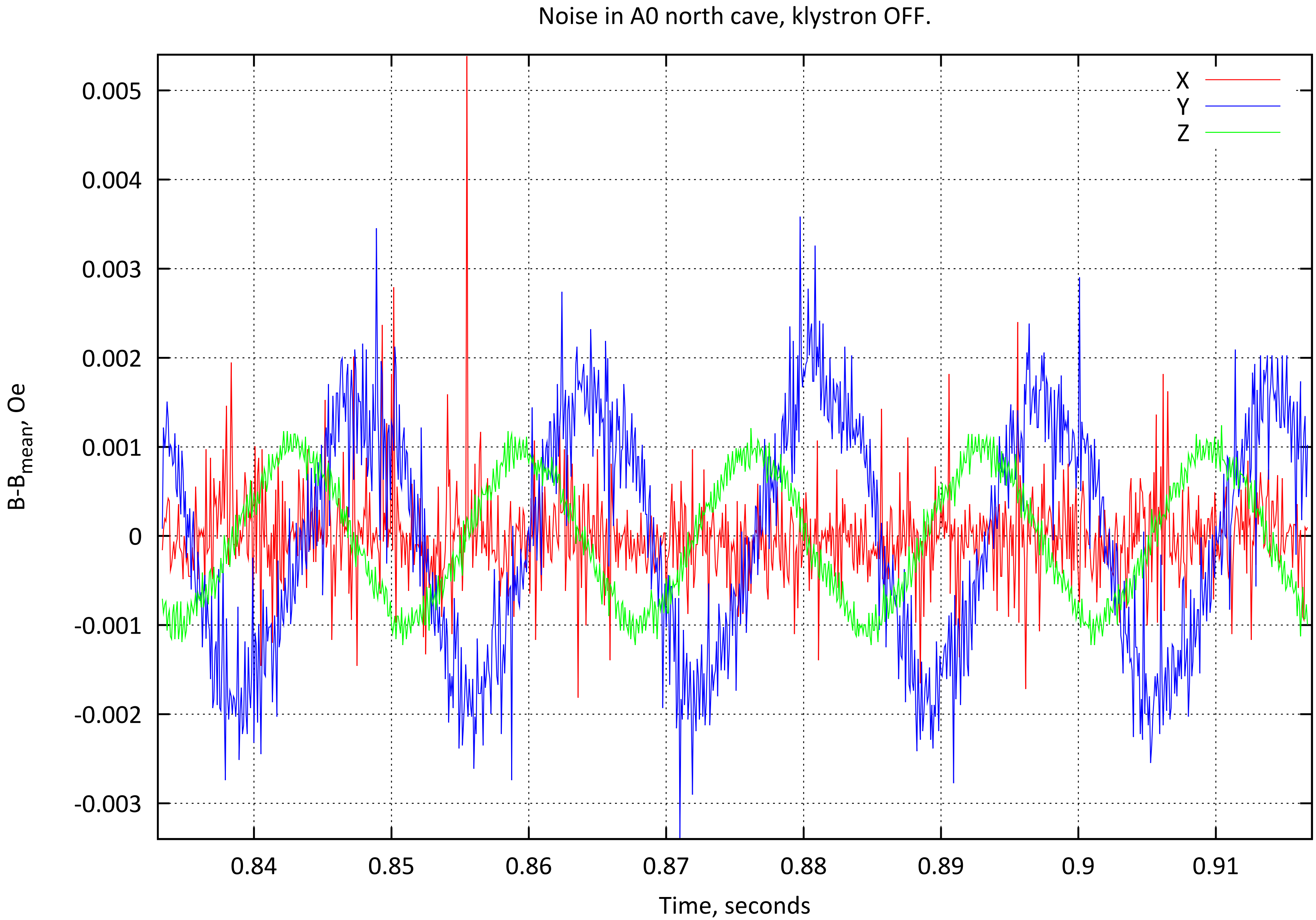
Fermilab data

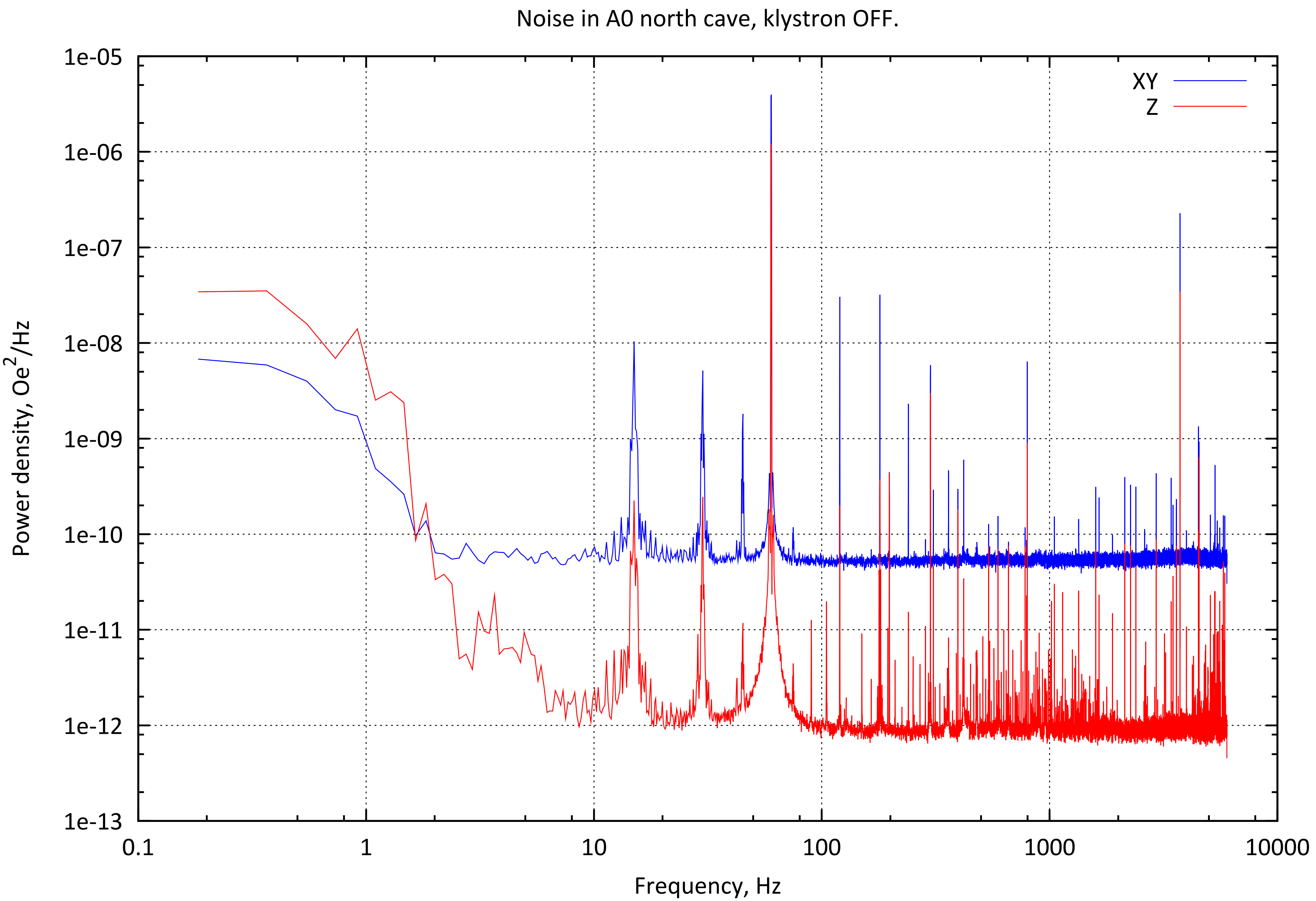
- Take data at **A0** experimental hall with 8 MW working klystron.
- Use 3-axis fluxgate magnetometer (Bartington Mag-03MC)
  - +/- 1mT full scale, DC to 3 kHz, 20 pT/sqrt(Hz)


2008/11/17

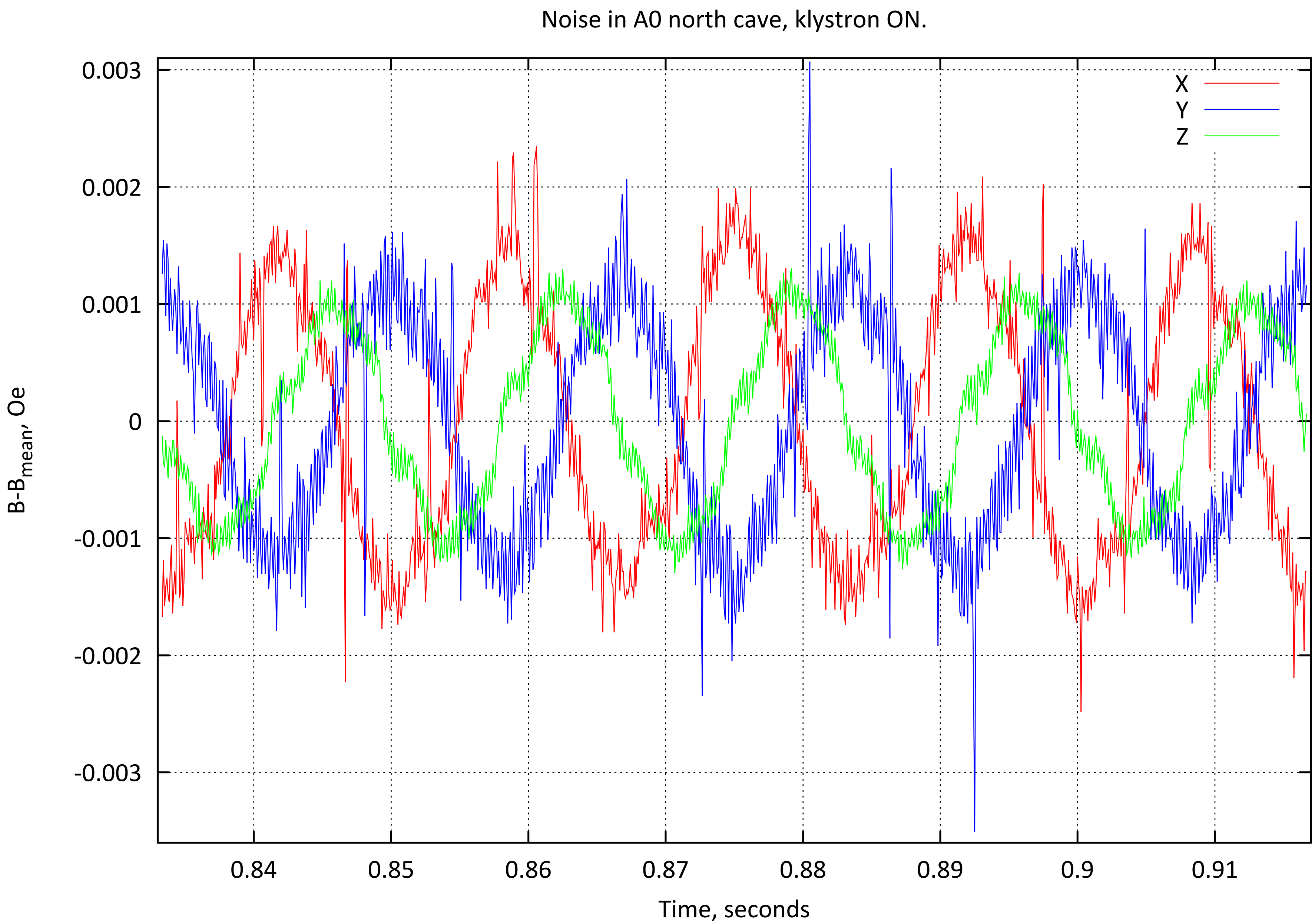

THOMSON TUBES
ELECTRONIQUES
KLYSTRON
3 MW RF WAVEGUIDE
HIGH VOLTAGE
TRANSFORMER
2008/11/07

Data taking at Fermilab

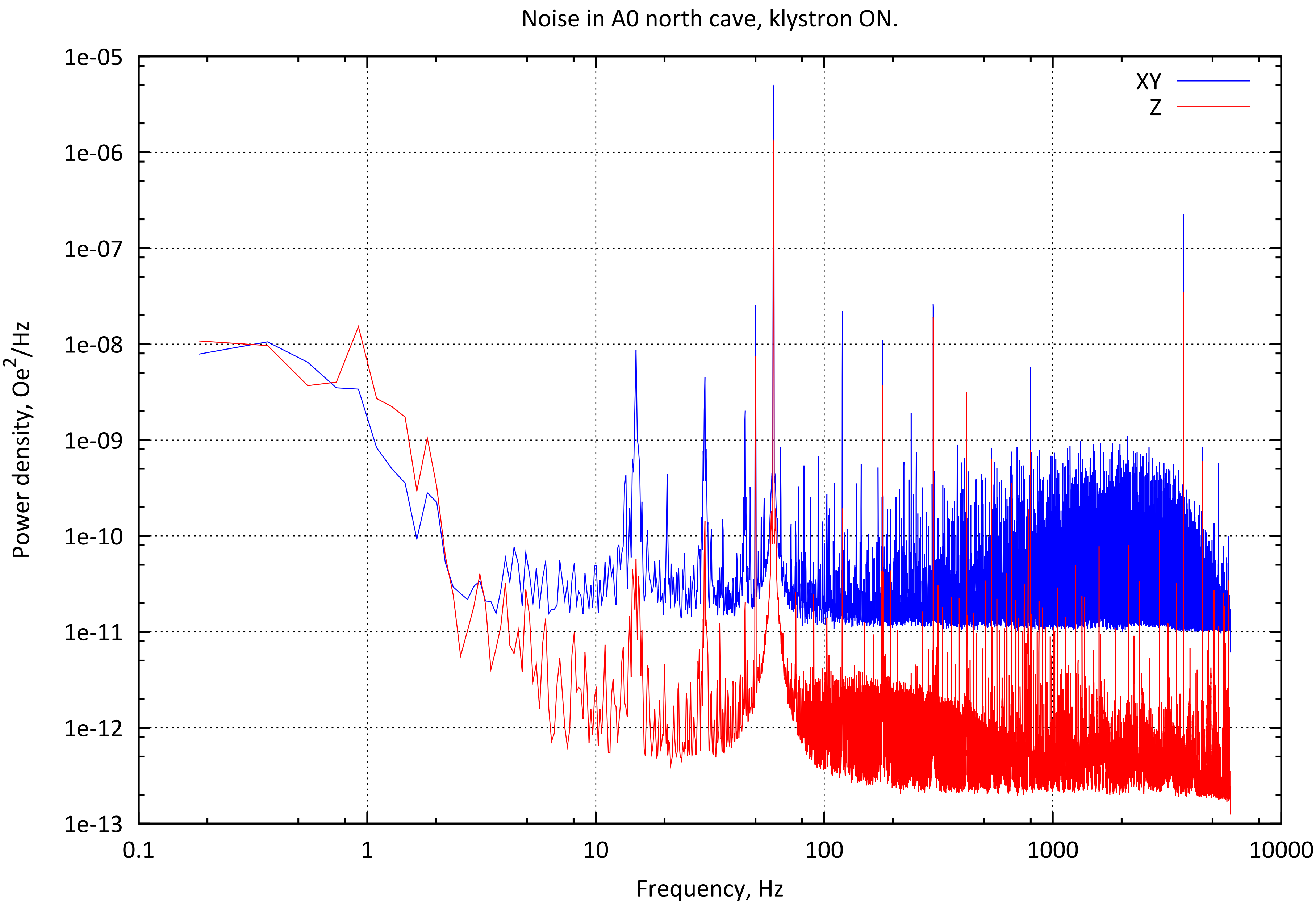

Noise in A0 north cave, klystron OFF.
X
Y
Z
B-B_mean, Oe
Time, seconds
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
0.84
0.85
0.86
0.87
0.88
0.89
0.9
0.91

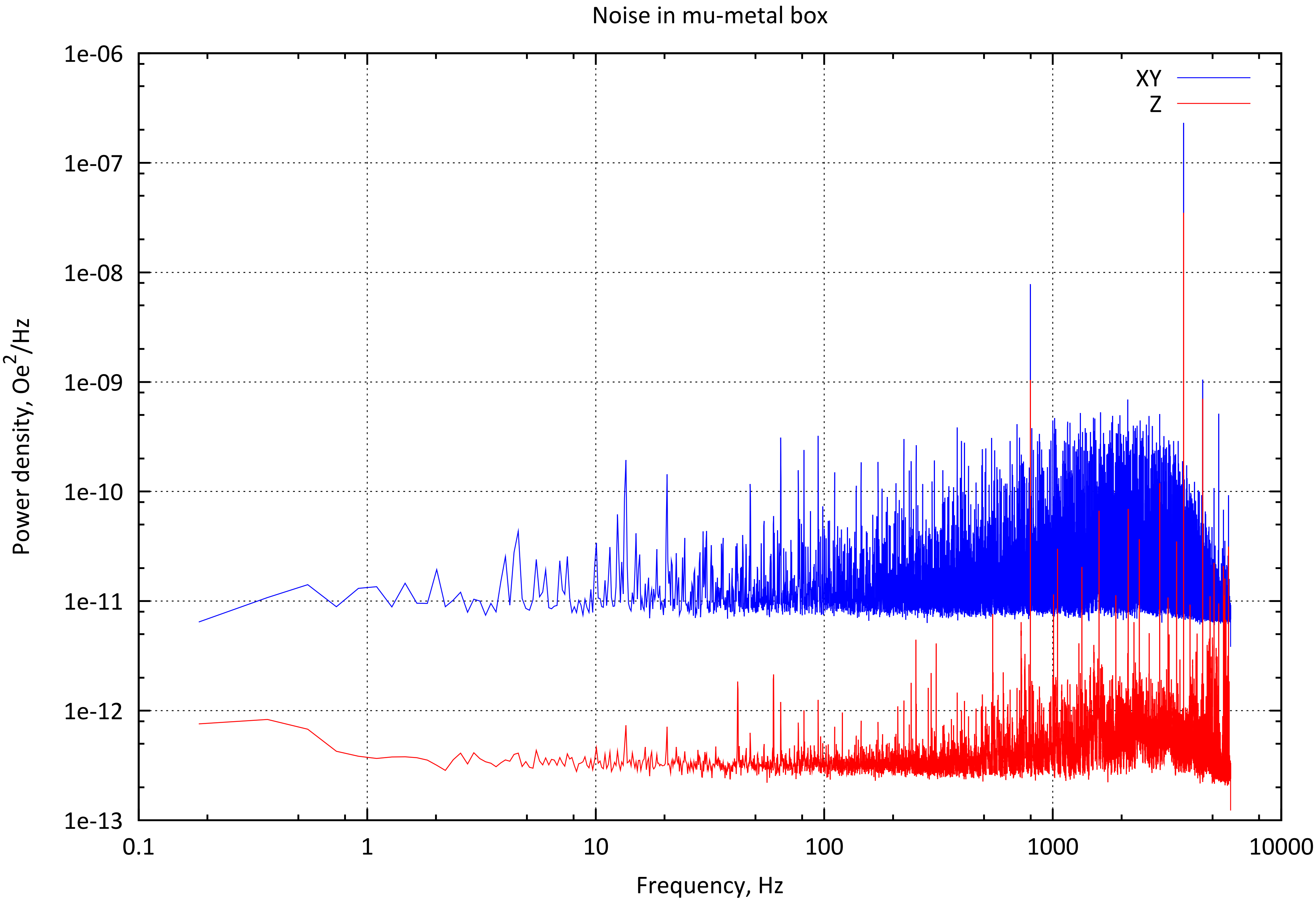


Noise in A0 north cave, klystron OFF.
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
0.1
1
10
100
1000
10000
XY
Z
Power density, Oe²/Hz
Frequency, Hz



Noise in A0 north cave, klystron ON.
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
$B\text{-}B_{mean}$, Oe
0.84
0.85
0.86
0.87
0.88
0.89
0.9
0.91
Time, seconds
X
Y
Z


Noise in A0 north cave, klystron ON.
XY
Z
Power density, Oe^2/Hz
Frequency, Hz
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
0.1
1
10
100
1000
10000



Noise in mu-metal box
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
0.1
1
10
100
1000
10000
Frequency, Hz
Power density, Oe²/Hz
XY
Z

Spectral energy balance sheet

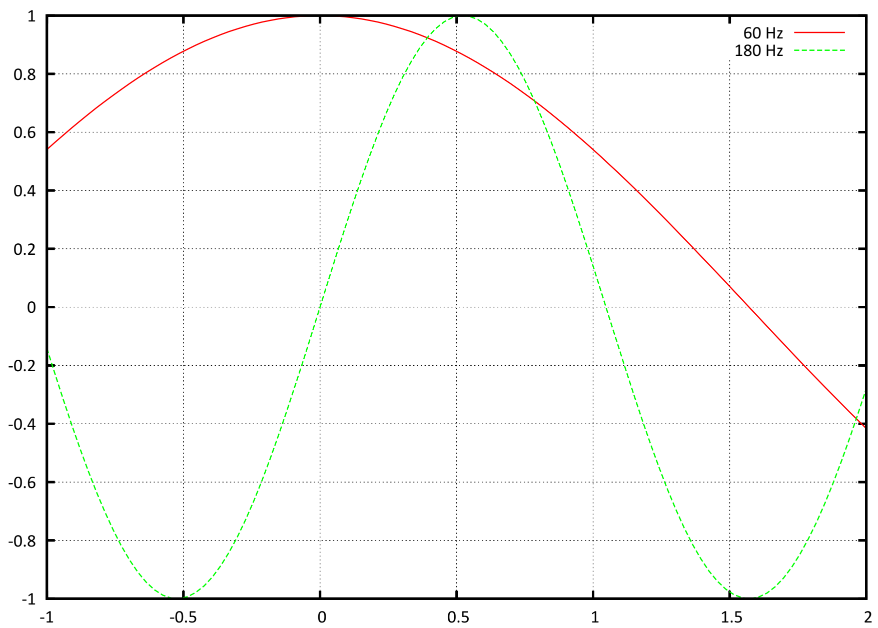
	Full	60, 120, 180, 240, 300	Full –line
Mumetal box	4.15e-4	6.7105e-06 4.9973e-06 5.8313e-06 9.2630e-06 4.5480e-06	
Klystron OFF	15.3e-4	1.3732e-03 8.8196e-05 1.0643e-04 2.6315e-05 5.5453e-05	6.6763e-04 (6.1524e-04 w/o 3734 Hz)
Klystron ON	16.1e-4	1.5134e-03 7.5403e-05 7.4083e-05 2.3624e-05 1.2948e-04	5.2351e-04 (4.5304e-04, w/o 3734 Hz)

"Klystron ON" - "Line" - "Mumetal box" = 1.8e-4 Oe

60 Hz issues...

- Can we *really* synchronize to 60 Hz?
- Even if we can, what about
  - Finite length of the bunch (1 msec)?
  - Finite wavelength of 60 Hz (10 km / 5000 km = 2e-4)

60 Hz – bunch length issue



Tune timing such that the bunch goes near the max or min of the 60-Hz signal. Then the middle of the bunch will see field change:
`1 – cos(2*pi*f*t/2) ~ 0.5*(pi*f*t)^2 = 0.017`
This is the effective level of 60 Hz signal with phase lock-in (reduced to 2% of the original amplitude).

If we control 60 Hz, we cannot control other harmonics. Worst case for 3d harmonic: `2*pi*(3f)*t => A3/A1 = pi*f*t/12=`**`0.016`**

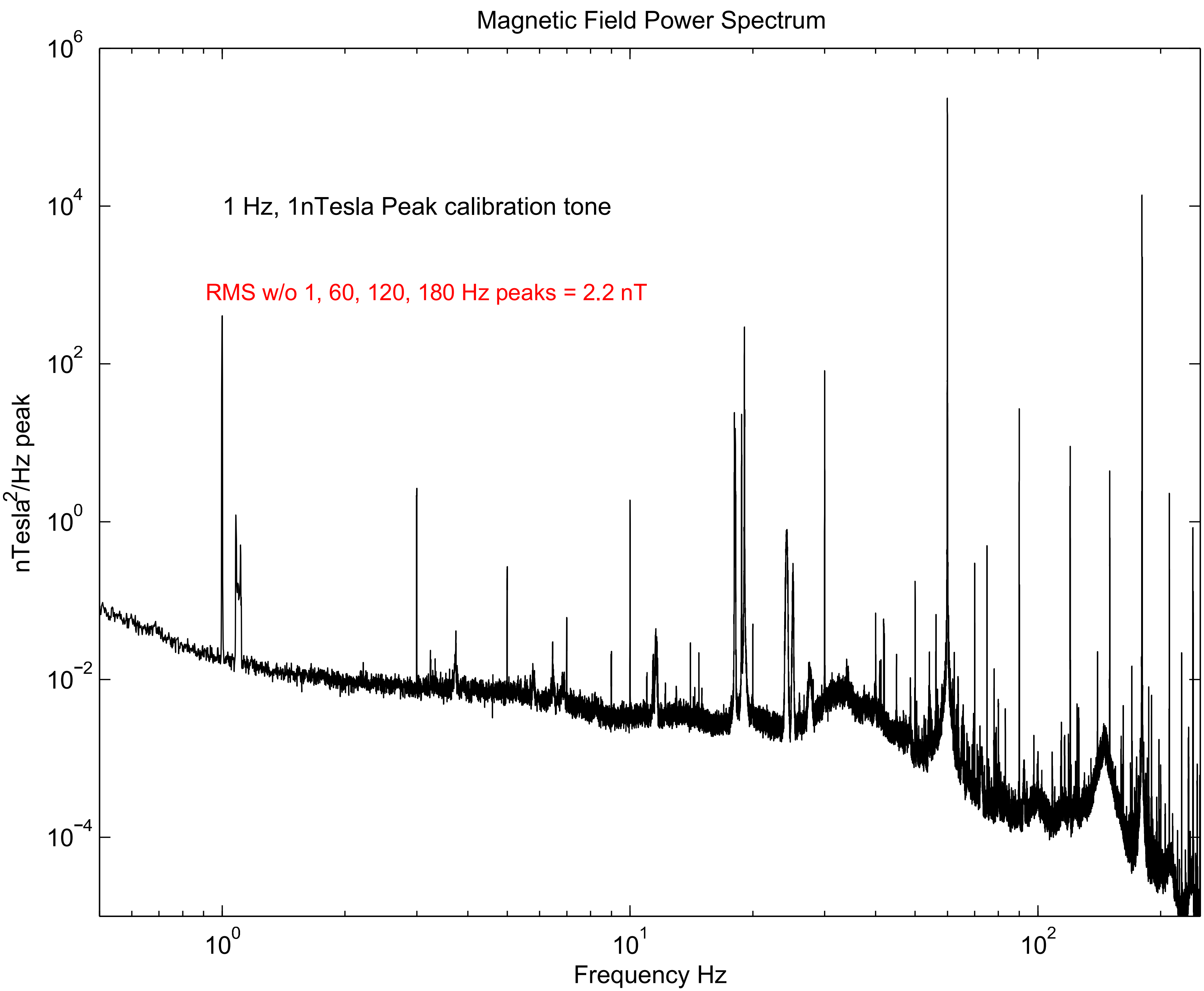
We have 0.05 to 0.07.

Similarly for 5th: A5/A1 = pi*f*t/20=**0.01**. We have 0.04 to 0.09

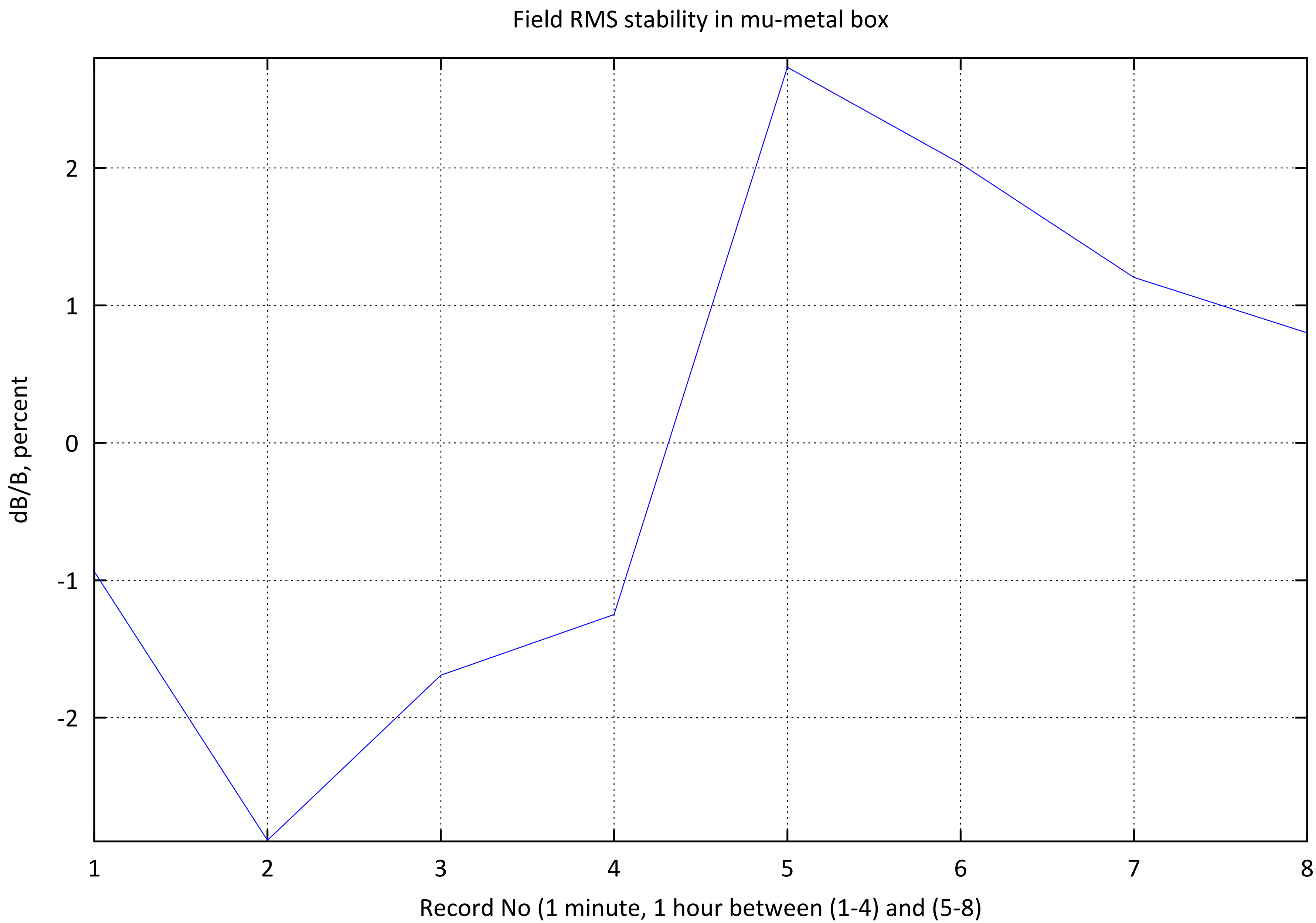
Future work

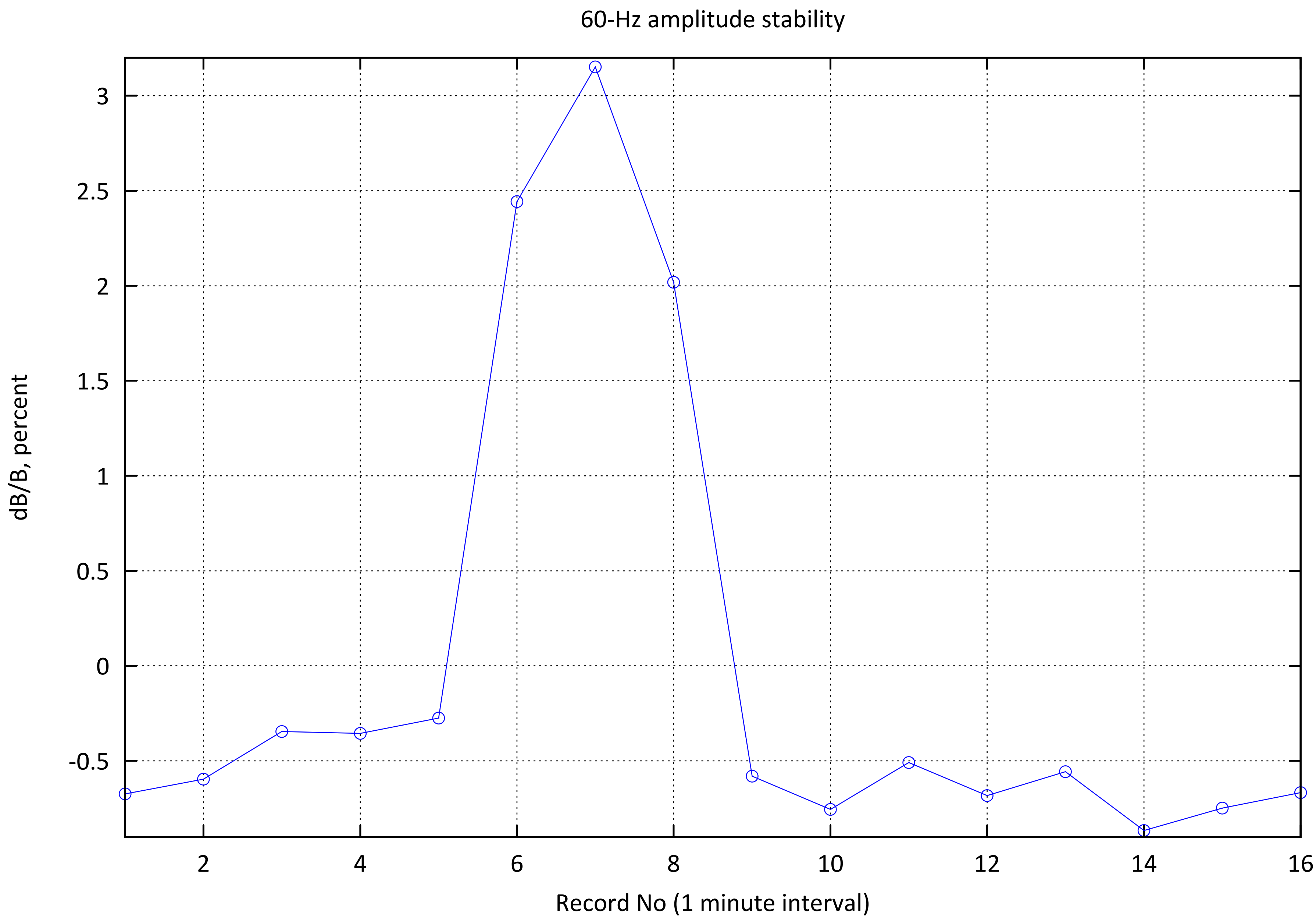
- 60 Hz is a challenge. Need to understand *finer* effects.
- We need more data!
  - Different sites; different locations on the same site.
  - Improve measurement techniques.
- Defensive design of RTML line:
  - Design in *provisions* for magnetic shielding?

Appendix



Frish,Raubenheimer,Tenenbaum, LCC-Note-0140


Field RMS stability in mu-metal box
dB/B, percent
2
1
0
-1
-2
1
2
3
4
5
6
7
8
Record No (1 minute, 1 hour between (1-4) and (5-8)


60-Hz amplitude stability
dB/B, percent
Record No (1 minute interval)
3
2.5
2
1.5
1
0.5
0
-0.5
2
4
6
8
10
12
14
16