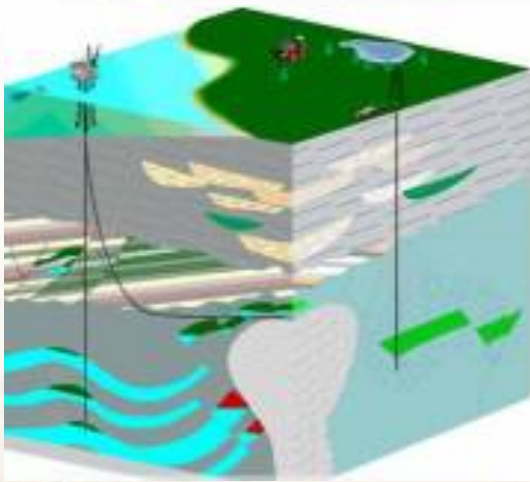




# **Combination of induction coil and fluxgate magnetometer for MT Sensor analysis and monitoring**

**Hanstein,T. K.M. Strack, and J. Jiang  
25<sup>th</sup> Schmucker-Weidelt Colloqium, Germany**

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# **Combination of induction coil and fluxgate magnetometer for MT Sensor analysis and monitoring**

**Tilman Hanstein\*\*, Kurt M. Strack\*, John Jiang\***

\*KMS Technologies – KJT Enterprises Inc., Houston Texas USA

\*\*KMS Technologies GmbH, Cologne Germany

25<sup>th</sup> Schmucker-Weidelt-Colloquium 2013





➤ Technology

- KMS product family & architecture

➤ Parallel sensor test

- Lemi118 (AMT), Lemi120 (MT) & EMI coils BF4, BF6

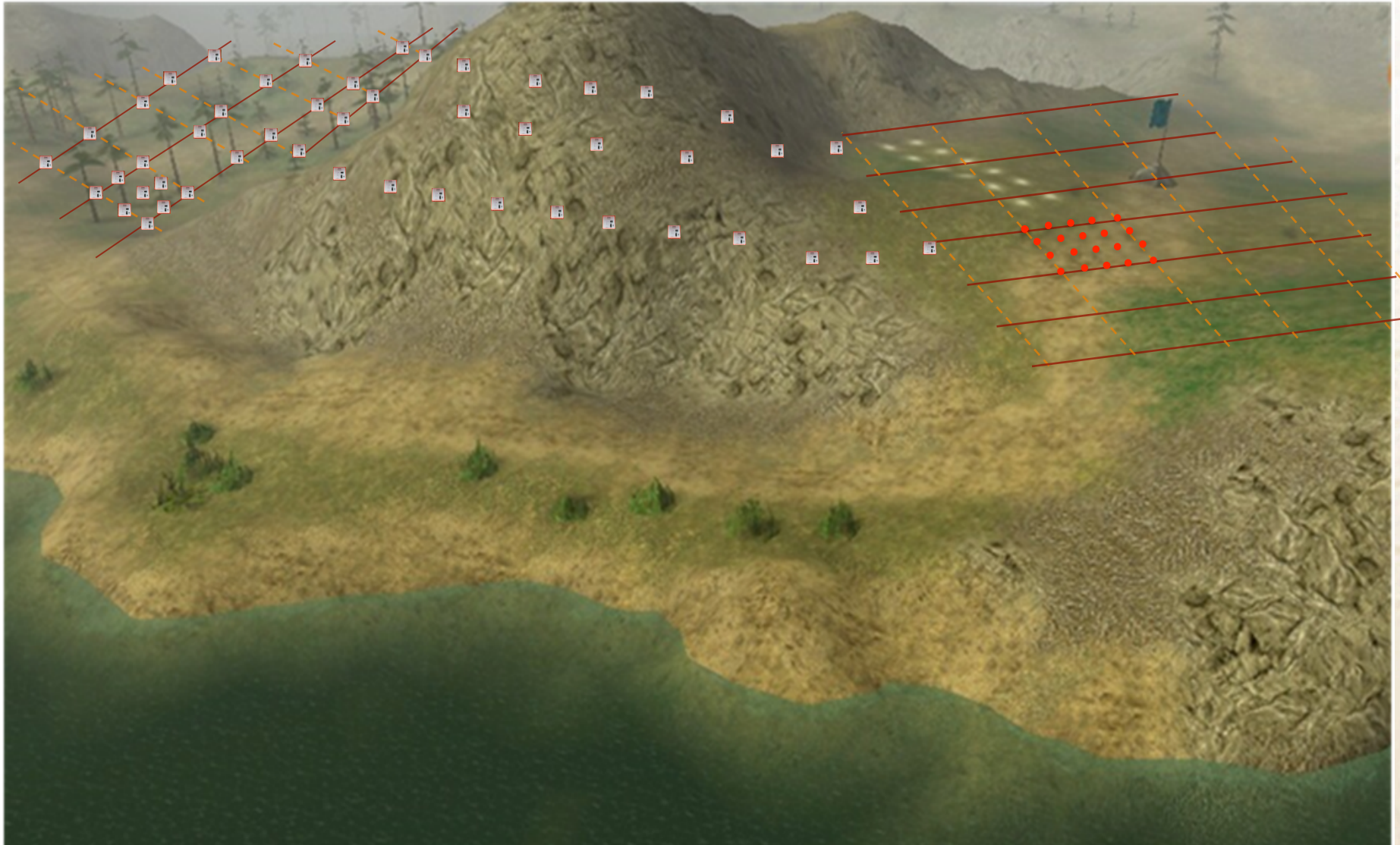
➤ MT

- High & low frequency and fluxgate magnetometer

➤ Monitoring

- India (earthquake), China (30-day experiment)

**Technology >> parallel sensor test >> MT >> monitoring**  
**KMS solution: layouts**





**Technology >> parallel sensor test >> MT >> monitoring**  
**KMS solution: layouts**







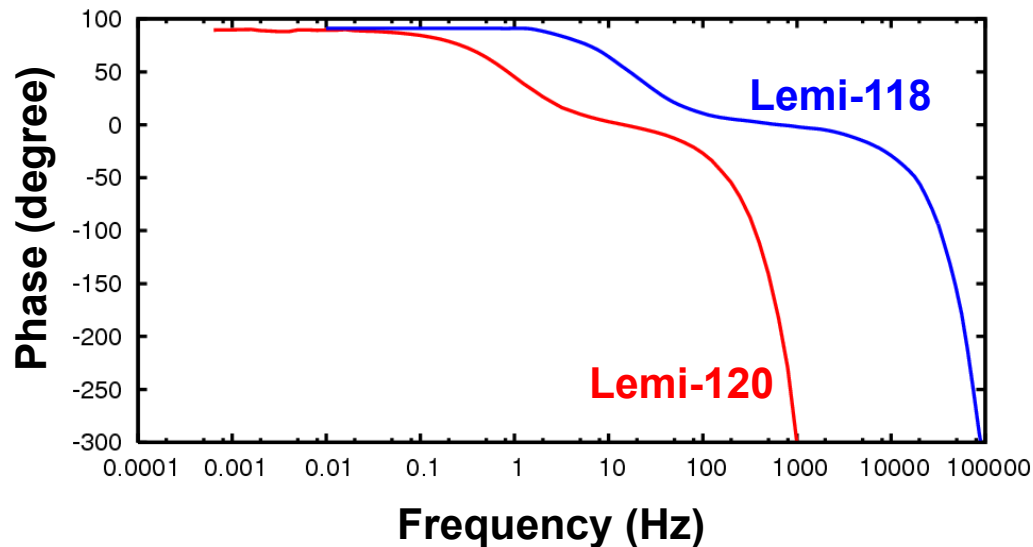
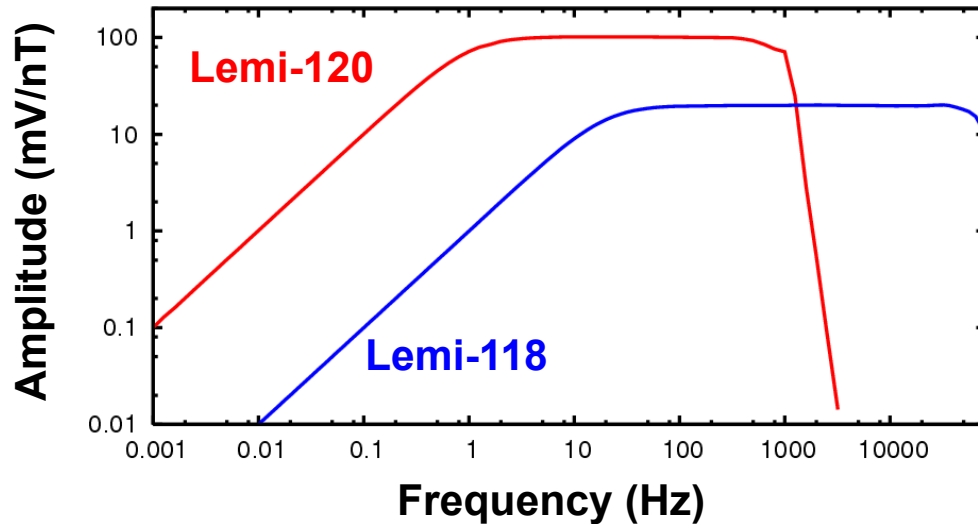
## **Technology >> parallel sensor test >> MT >> monitoring specifications**

- **Low power consumption**
  - Uses between 3 to 5 W (comp. 15-20 W)
  - All channels are switchable
- **Large dynamic range**
  - 24 Bit
- **High bandwidth**
  - DC, sampling rate 40 Hz to 80 kHz
- **Communication**
  - Wireless & Wi-Fi (switchable), USB
  - SD-card with recording schedule
- **GPS**
  - Switchable & timing
- **A general-purpose acquisition system (MT & CSEM)**
  - ALL EM methods and also microseismics
  - The system is broadband and fully firmware controlled





**Technology >> parallel sensor test >> MT >> monitoring**  
**Magnetic sensors: Induction coil response**



**MT**      **low frequency**

**Lemi-120**

**Frequency band**  
**0.1 mHz – 1 kHz**

**L = 1.34 m, W = 6 kg**

**also tested EMI: BF-4**

**AMT**      **high frequency**

**Lemi-118**

**Frequency band**  
**1 Hz – 70 kHz**

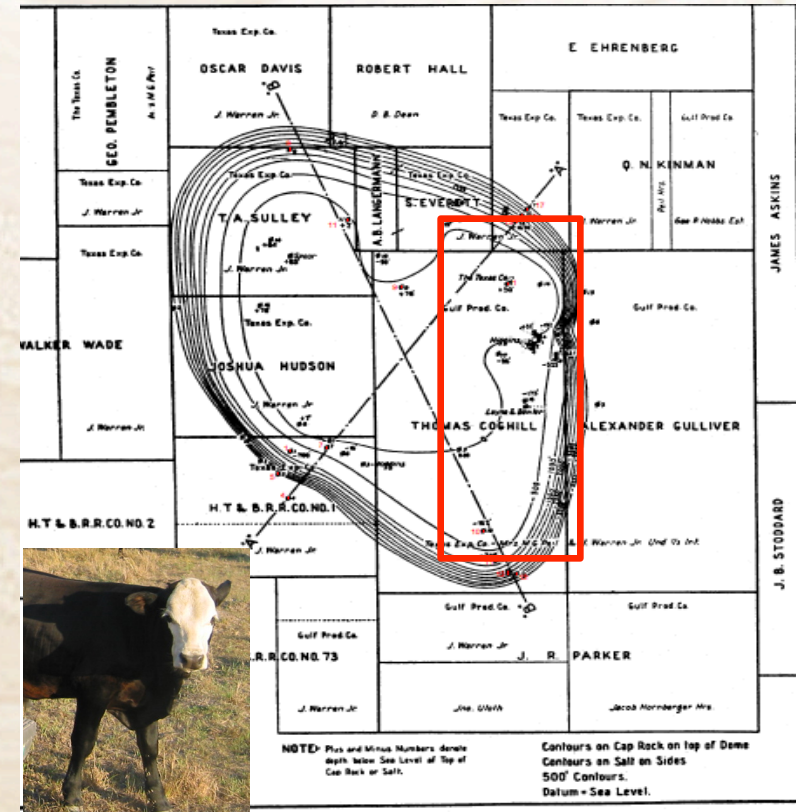
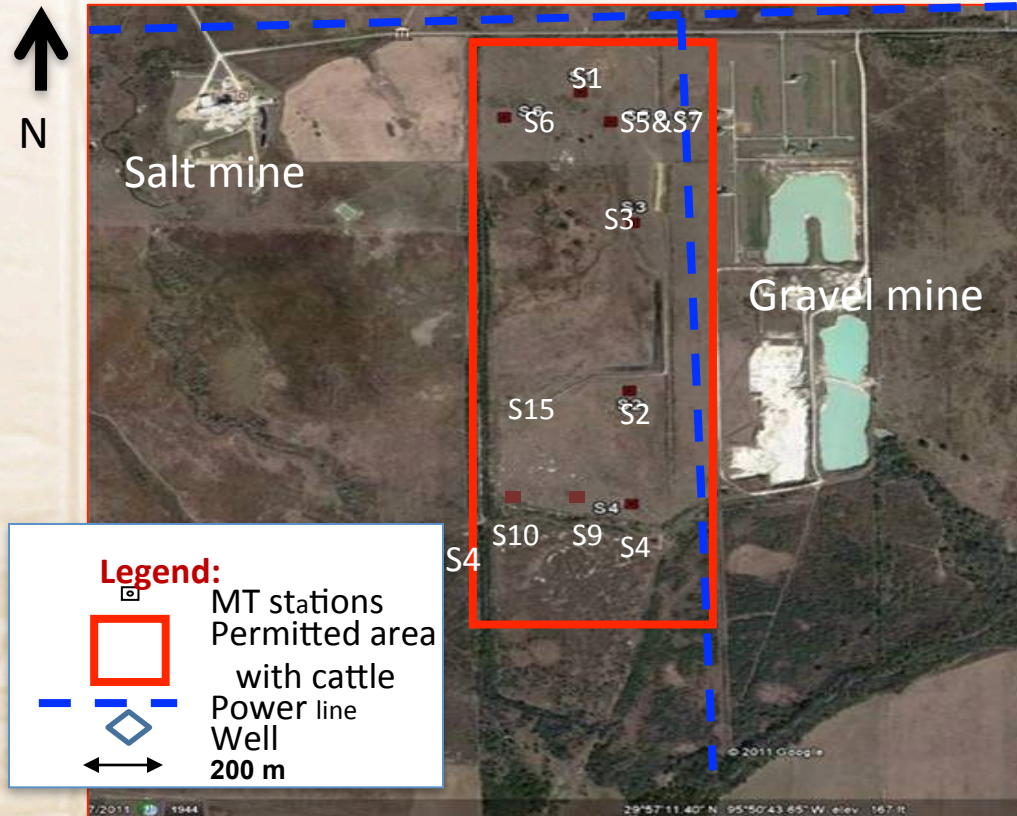
**L = 0.85 m, W = 1.7 kg**

**also tested EMI: BF-6**



## Salt overhang in NOISY environment – Houston suburbia Hockley salt dome map with MT stations

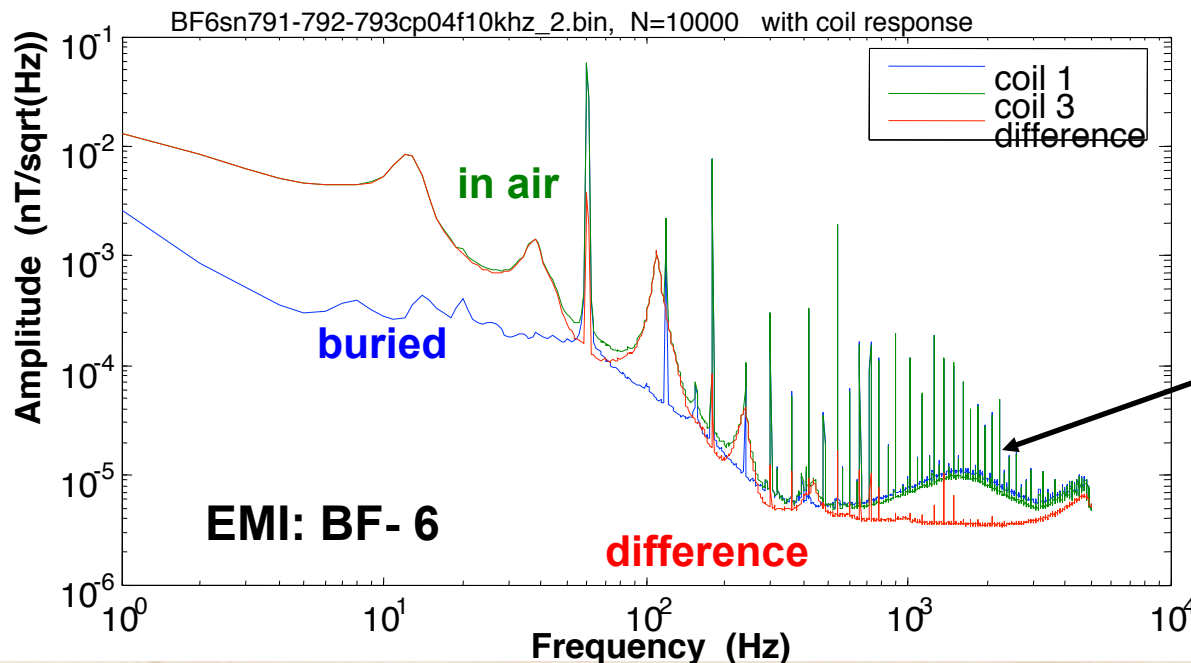
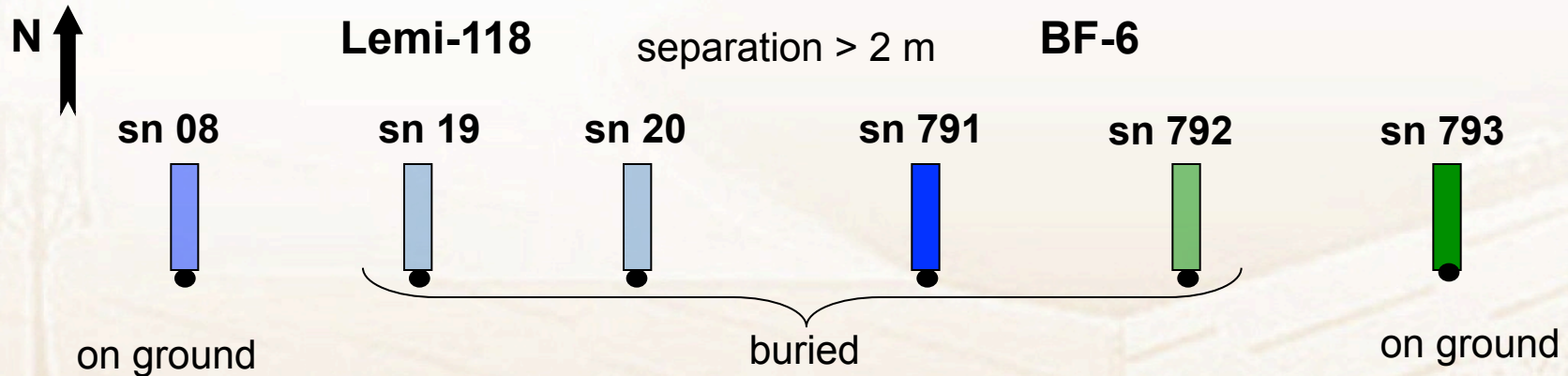
◇ **Direct Warren well**



Deussen A. et al.

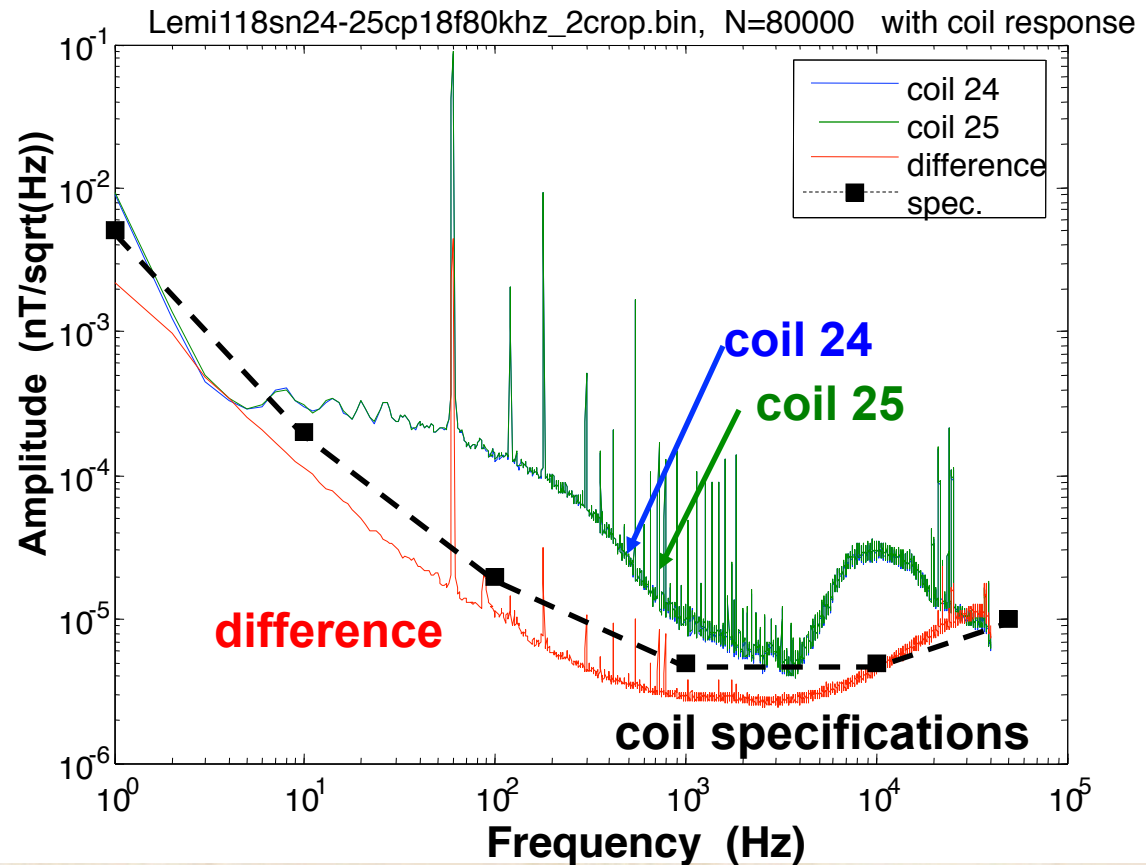
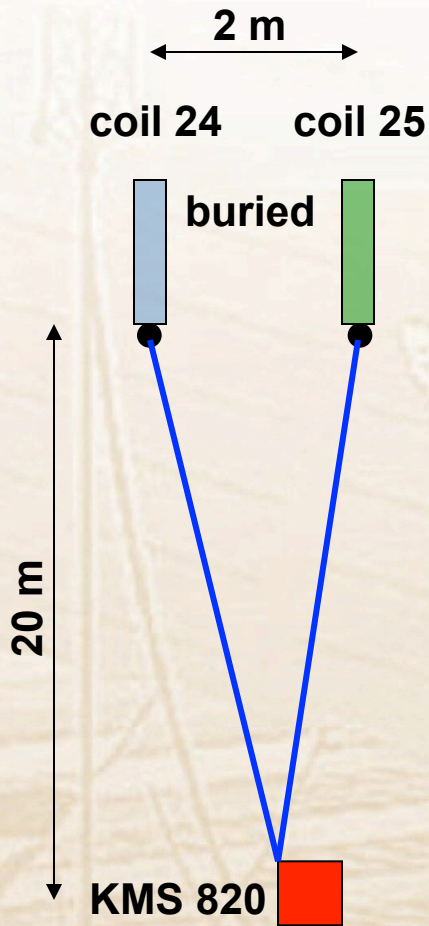


Technology >> **parallel sensor test** >> MT >> monitoring  
**Set up**



Strange peak  
where dead  
band at 2 kHz is  
expected

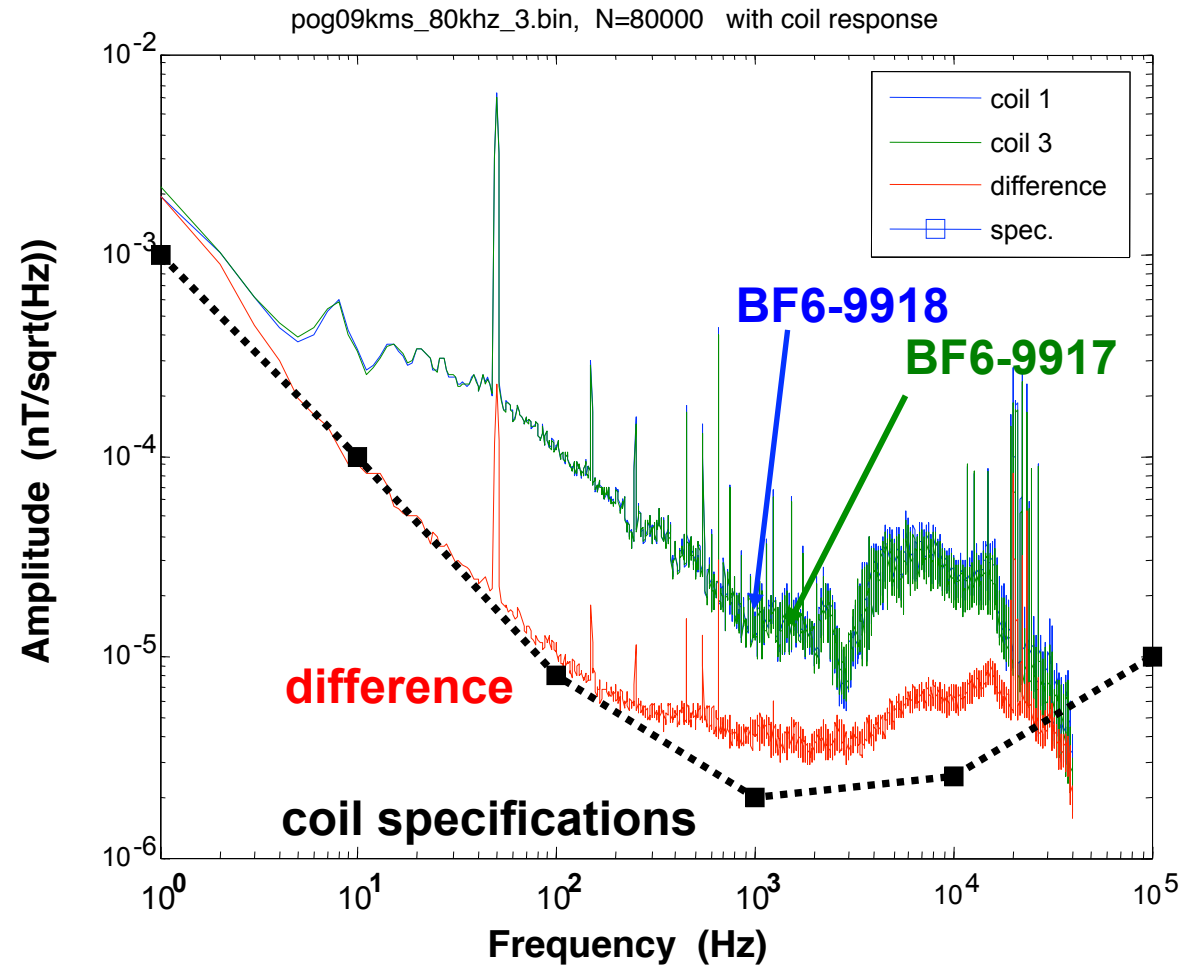
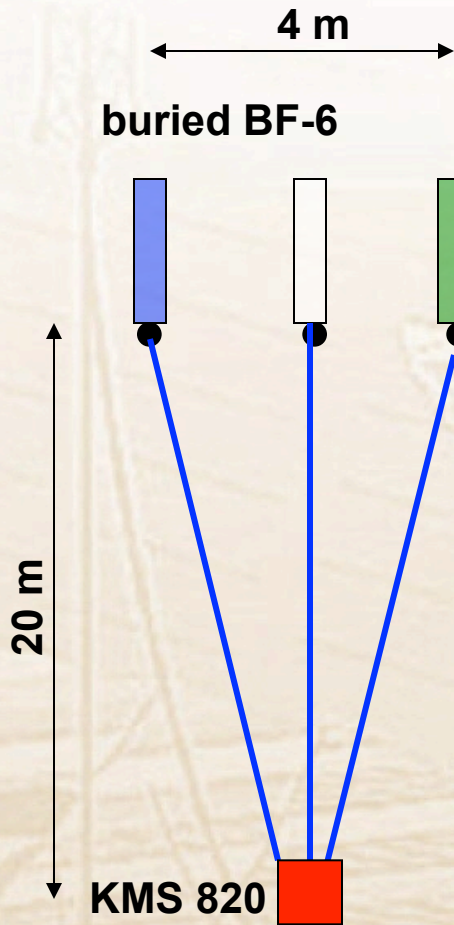
Observed when  
when external  
field is small



**difference of complex spectra**

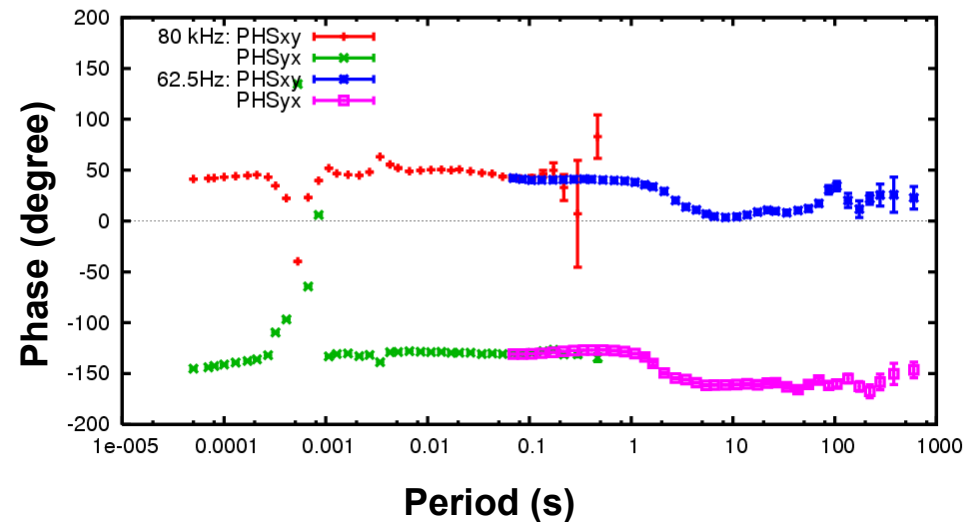
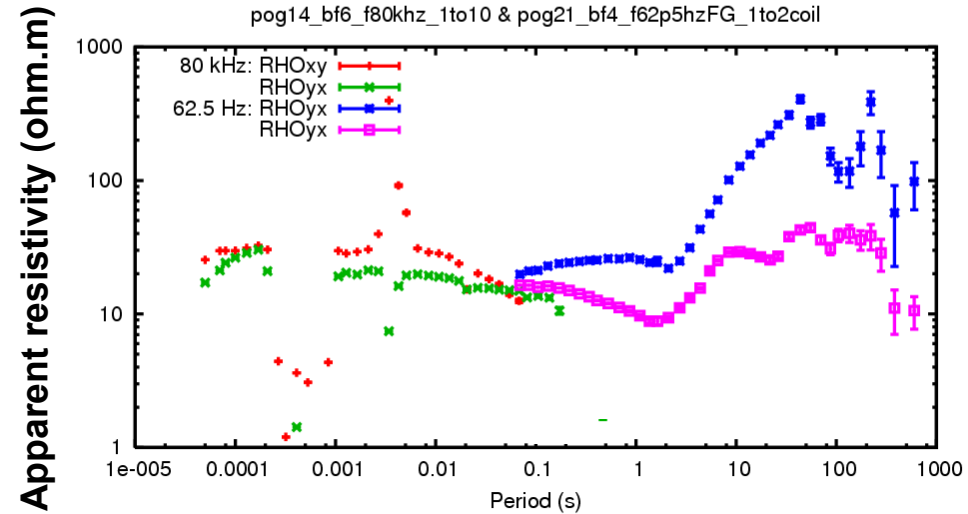
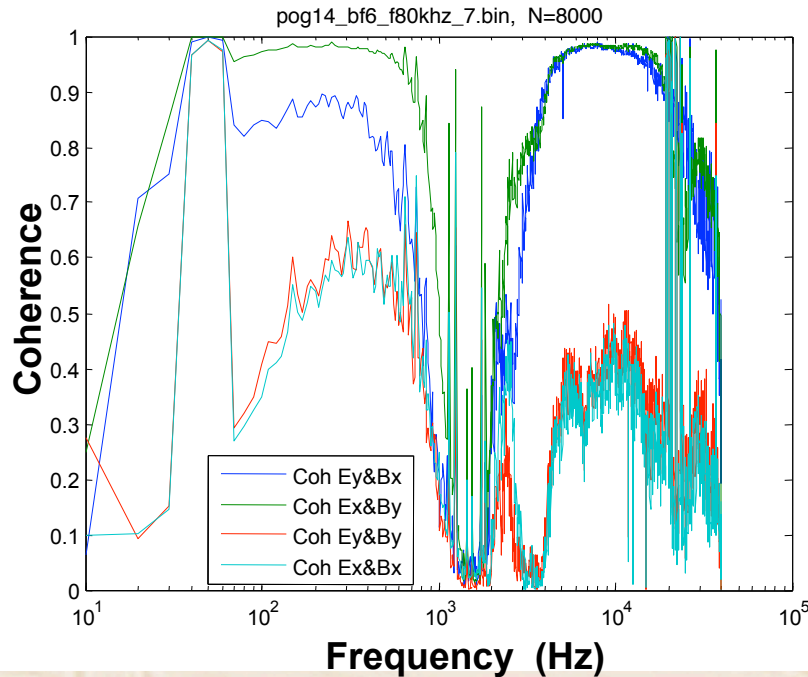


Technology >> **parallel sensor test** >> MT >> monitoring  
**BF-6: noise performance, 80 kHz sampling rate (Italy)**



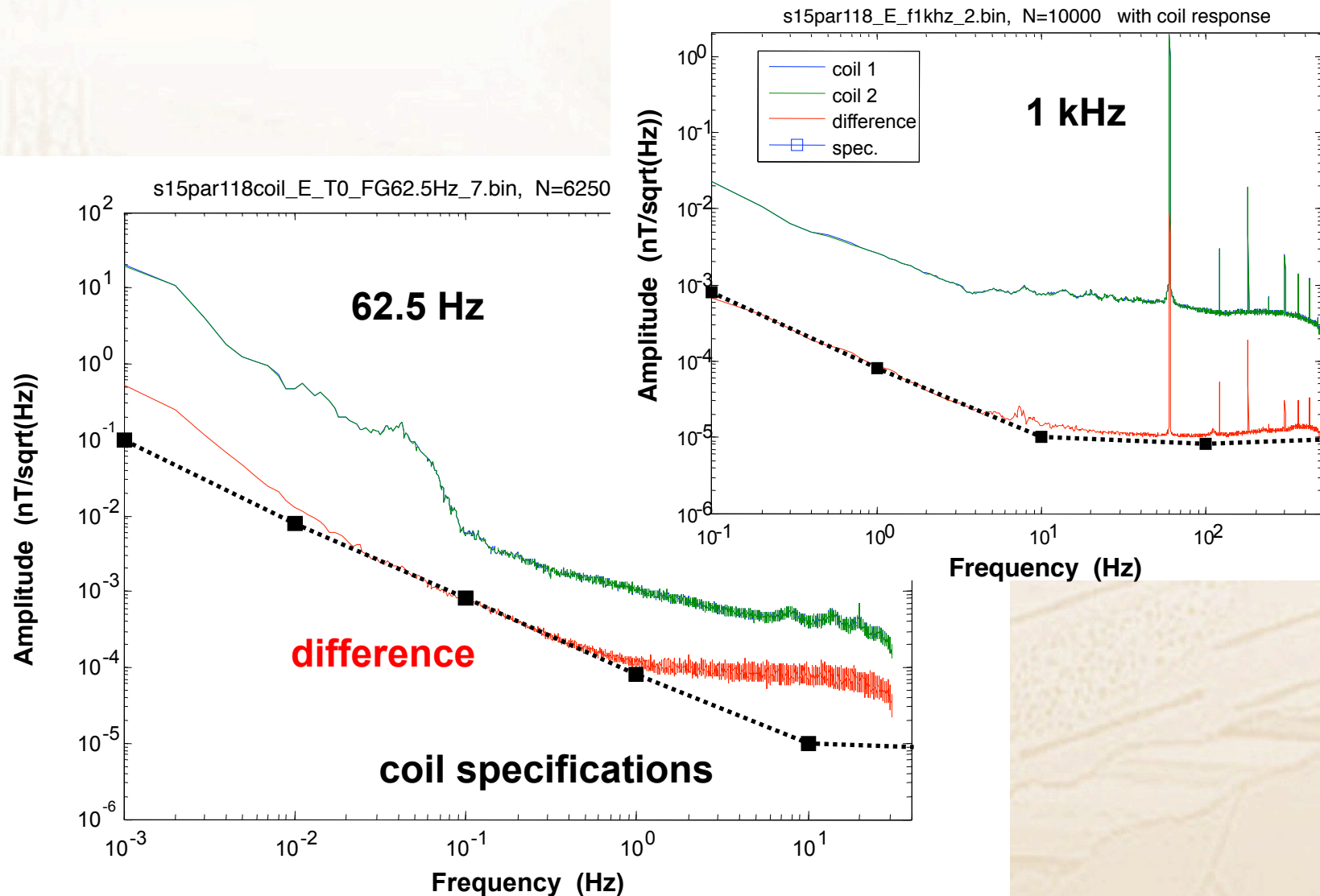
# Technology >> parallel sensor test >> MT >> monitoring

## BF-6: AMT, 80 kHz sampling rate (Italy)





Technology >> **parallel sensor test** >> MT >> monitoring  
**Lemi-120 : noise performance, low frequency MT**





Technology >> **parallel sensor test** >> MT >> monitoring  
**set up vertical induction coil**



Set up & bury vertical component is an issue

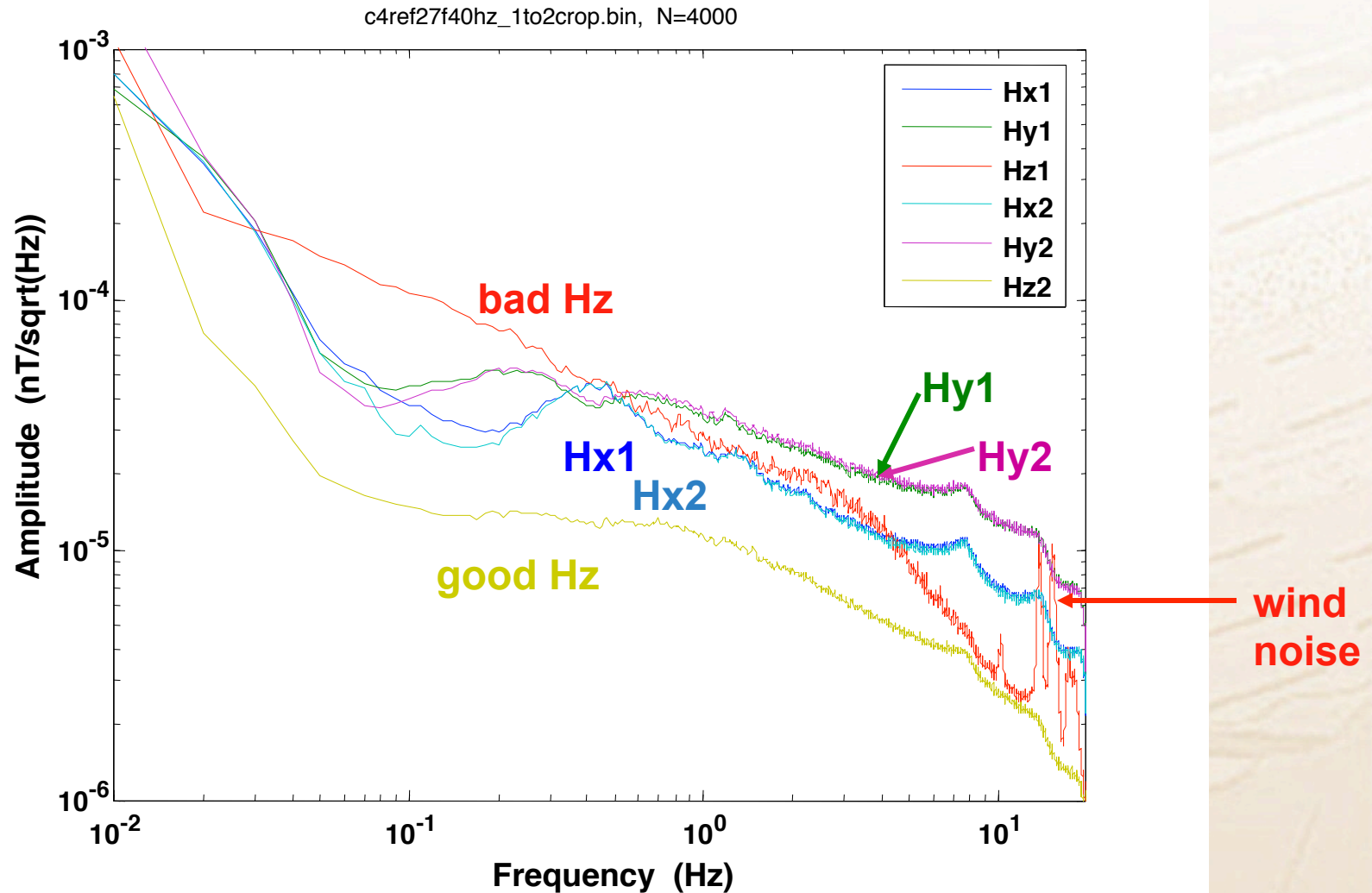
Sometimes:  
proper way not possible  
→ alternatives



Smaller size → fluxgates



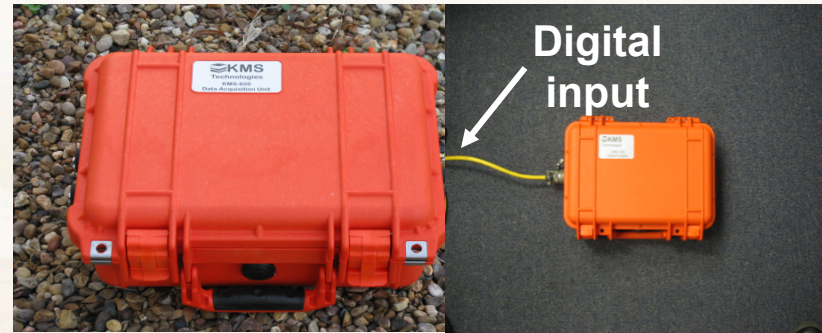
# Technology >> parallel sensor test >> MT >> monitoring magnetic recordings of 2 parallel stations



Technology >> **parallel sensor test** >> MT >> monitoring  
**Digital 3-C fluxgate magnetometer**



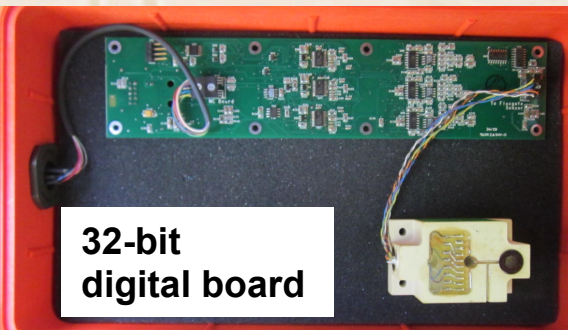
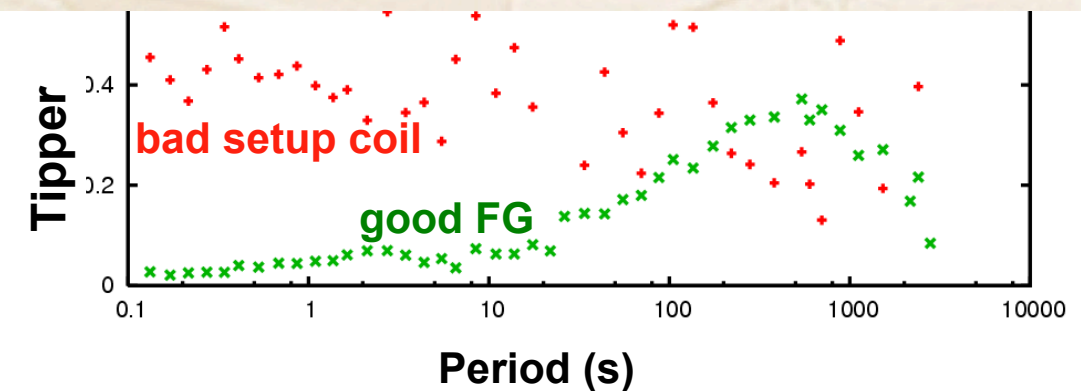
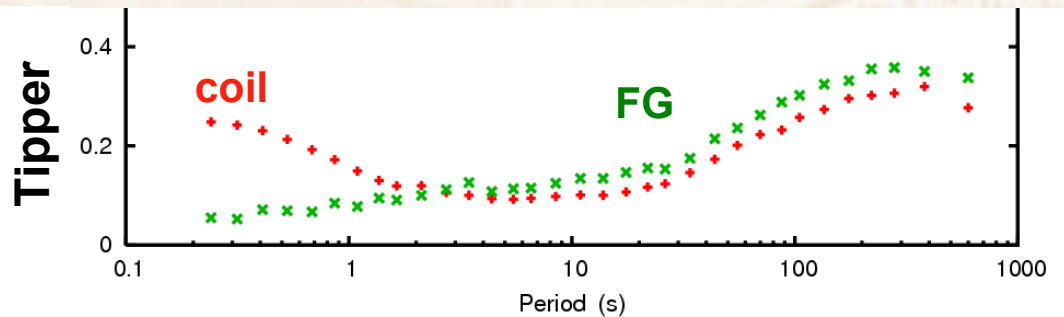
**Analogue input (6 ch)**  
MT: Hx, Hy, Hz, Ex, Ey



**Fluxgate magnetometer**

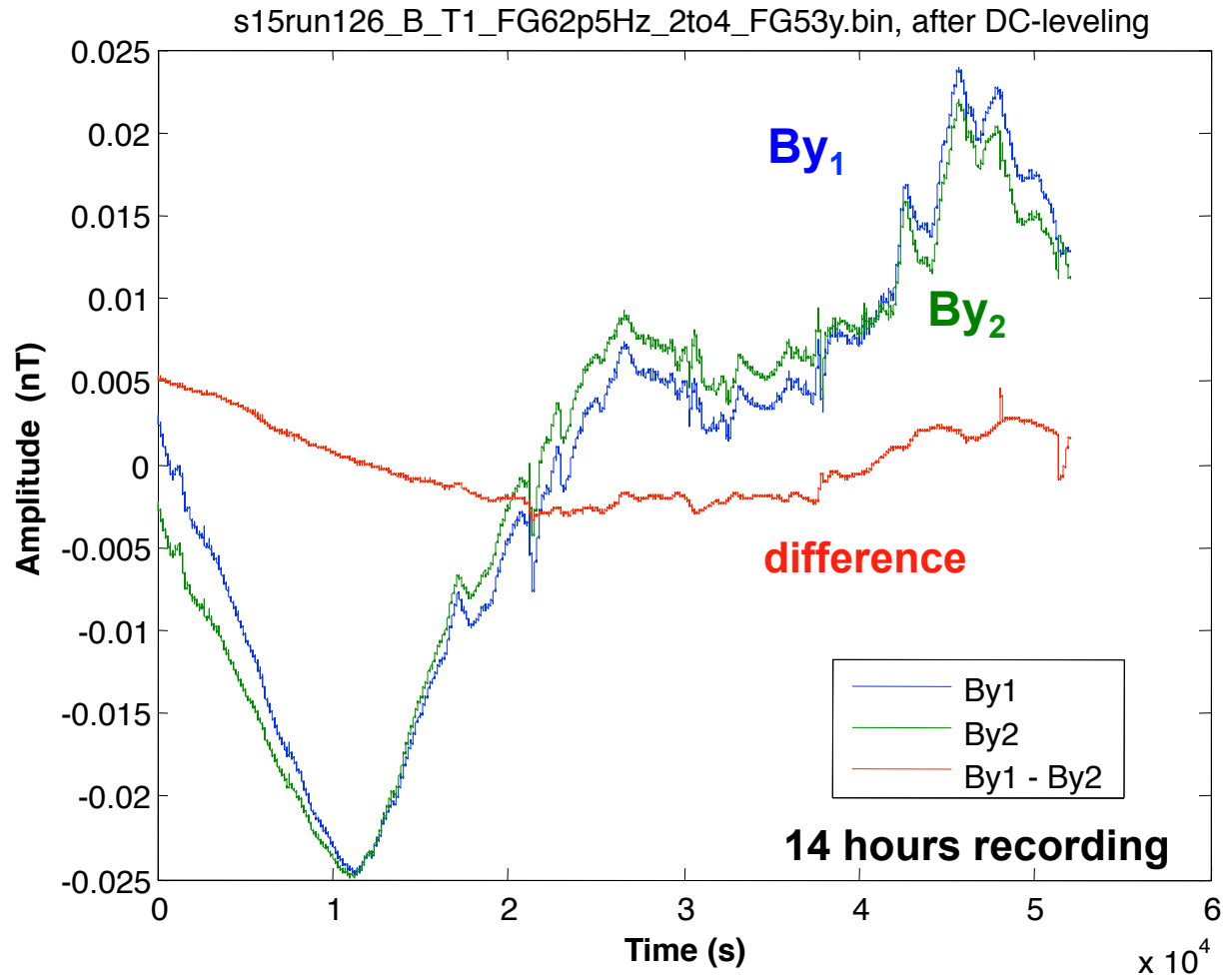
Digital, 3 component

DC to 180 Hz

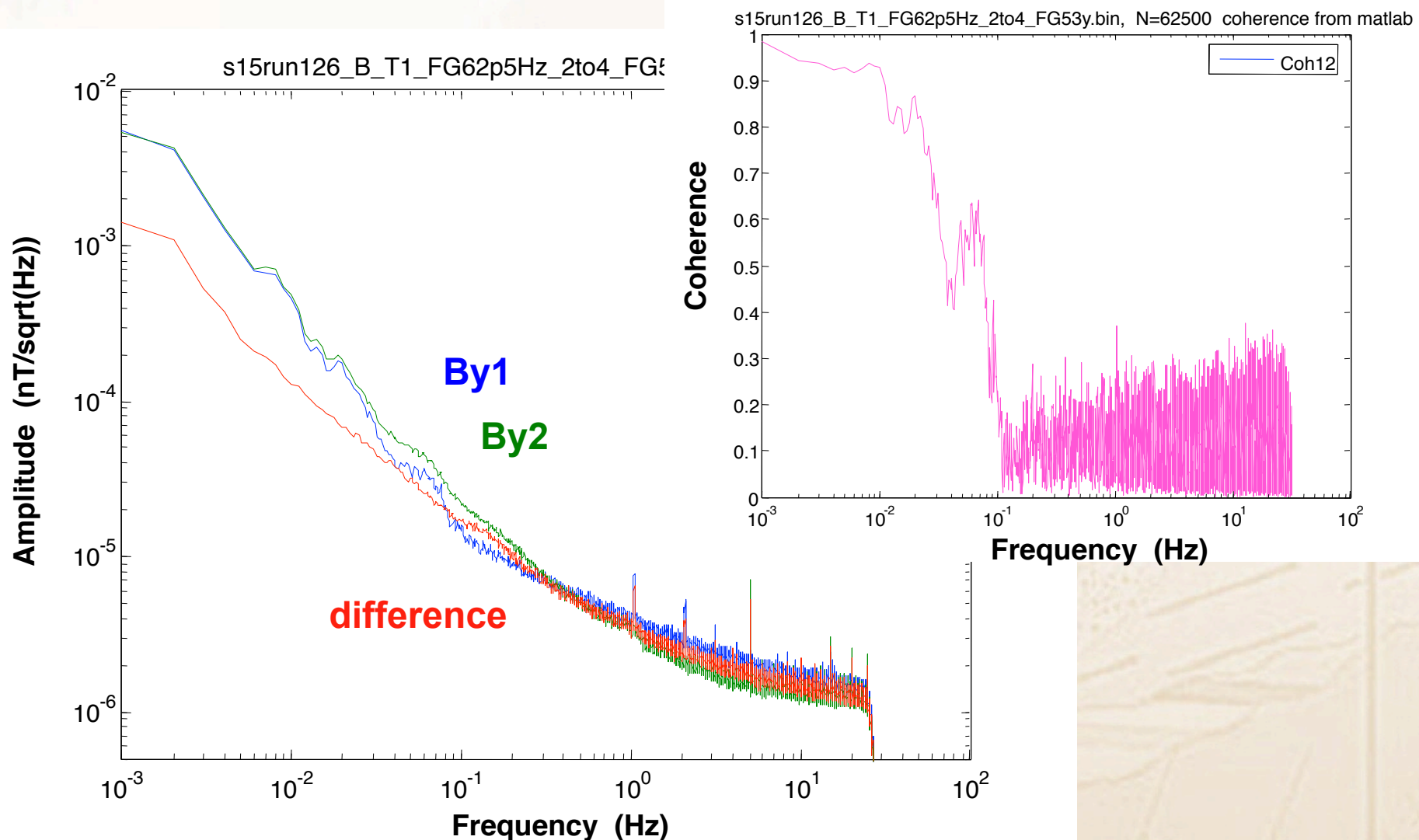


max. sampling 4 kHz



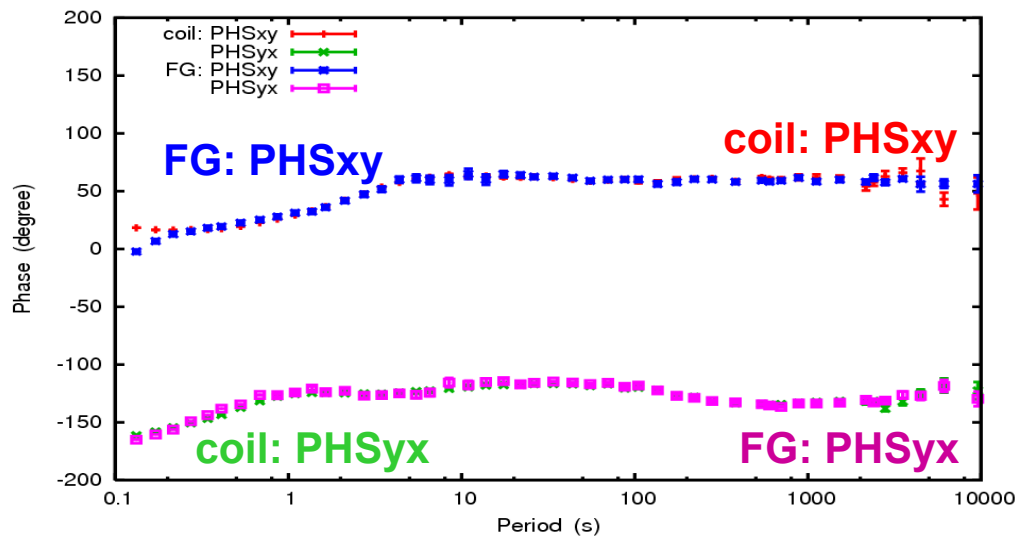
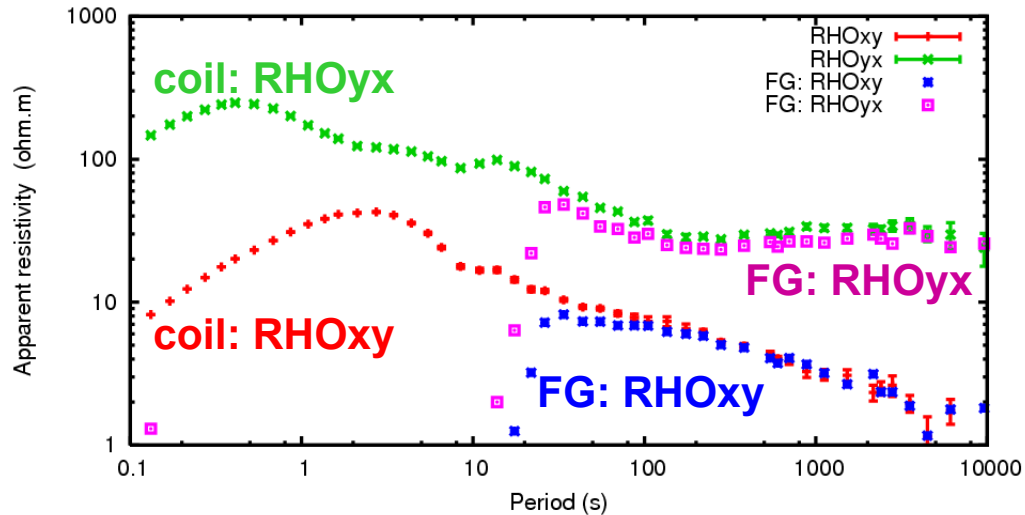


# Technology >> parallel sensor test >> MT >> monitoring noise performance & coherence for fluxgate magnetometer





# Technology >> parallel sensor test >> MT >> monitoring Fluxgate magnetometer & induction coils



$$E = Z H$$

Estimation of transfer function  $Z$

Input  $H_x$  &  $H_y$

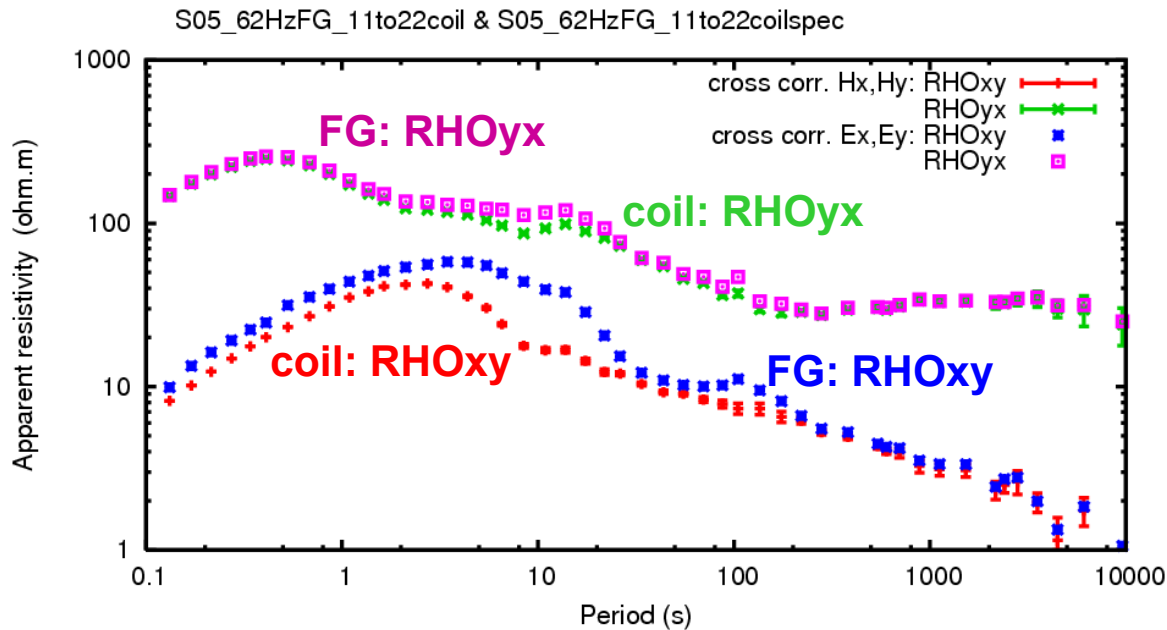
assumed  
to be noise free

If not  $\rightarrow$  bias to

Output:  $E_x$  &  $E_y$

**Phase is not biased**

Technology >> parallel sensor test >> **MT** >> monitoring  
**Fluxgate magnetometer with improved transfer function**



$$\mathbf{H} = \mathbf{Z}^{-1} \mathbf{E}$$

Estimation admittance

Input Ex & Ey

assumed  
to be noise free

Less noise than FG

Output: Hx & Hy



Technology >> parallel sensor test >> MT >> **monitoring**  
**different runs on 5 different days**



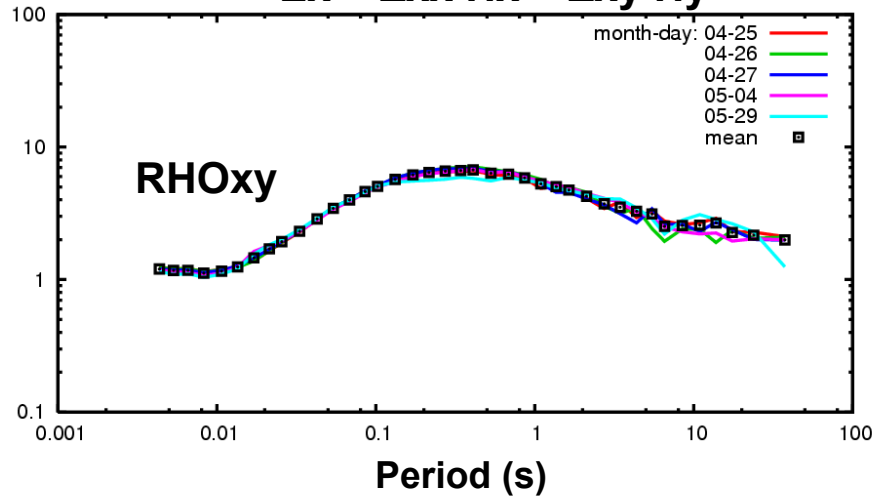
**Magnetotelluric**

$$E = Z H$$

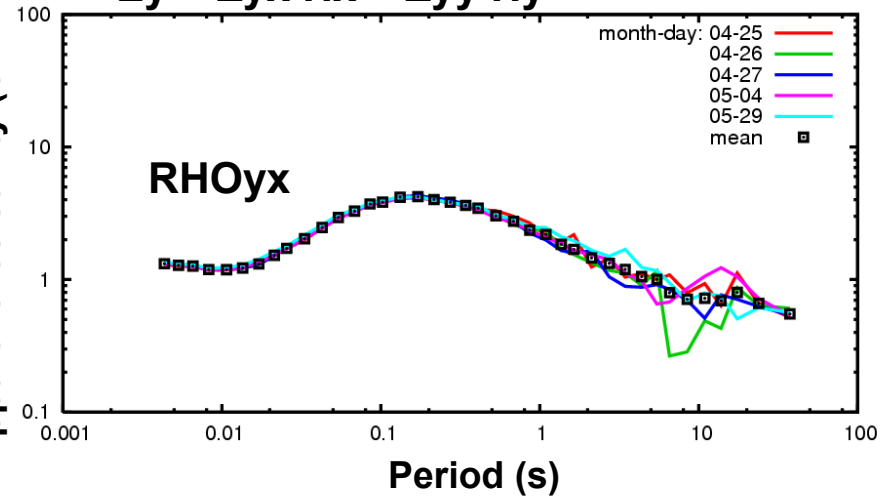
$$E_x = Z_{xx} H_x + Z_{xy} H_y$$

$$E_y = Z_{yx} H_x + Z_{yy} H_y$$

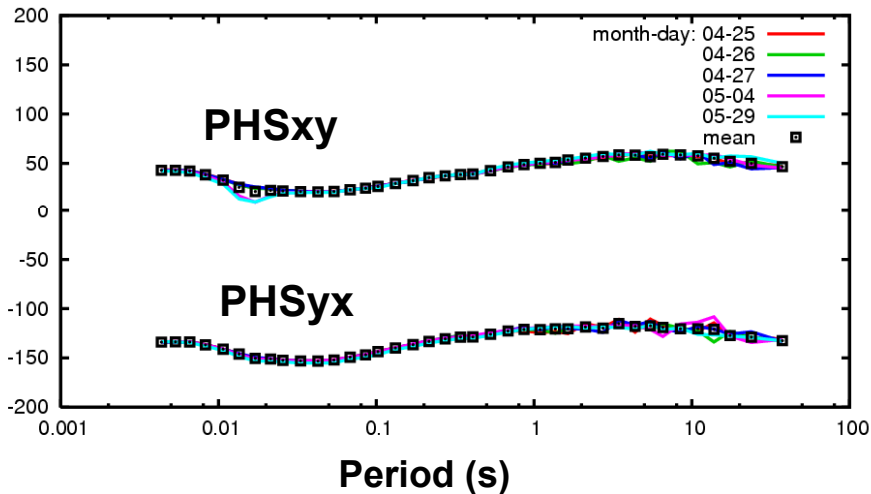
Apparent resistivity (ohm.m)



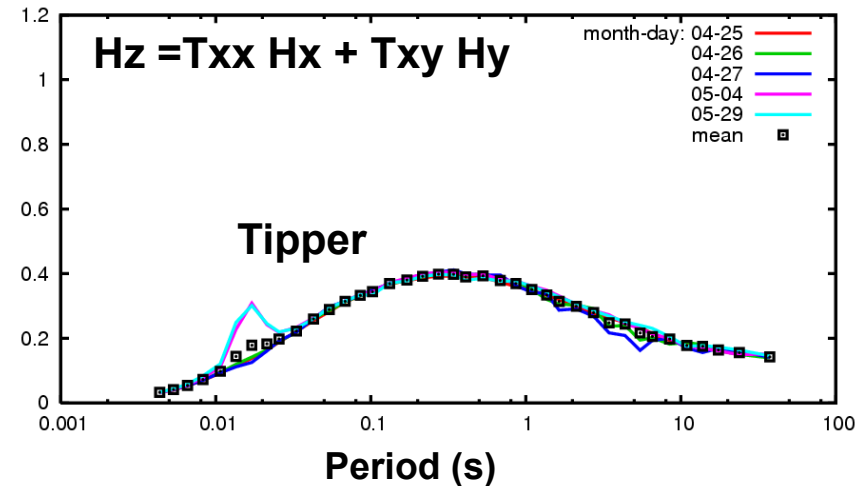
Apparent resistivity (ohm.m)



Phase (degree)



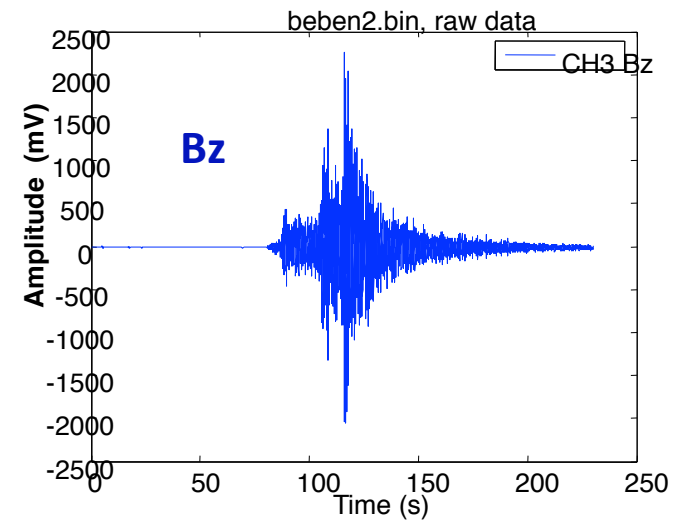
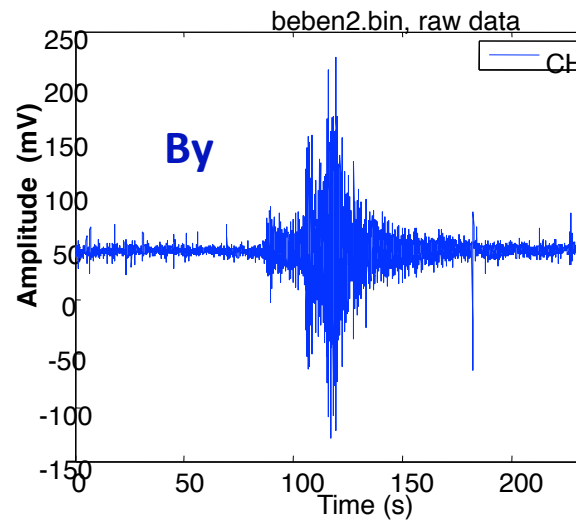
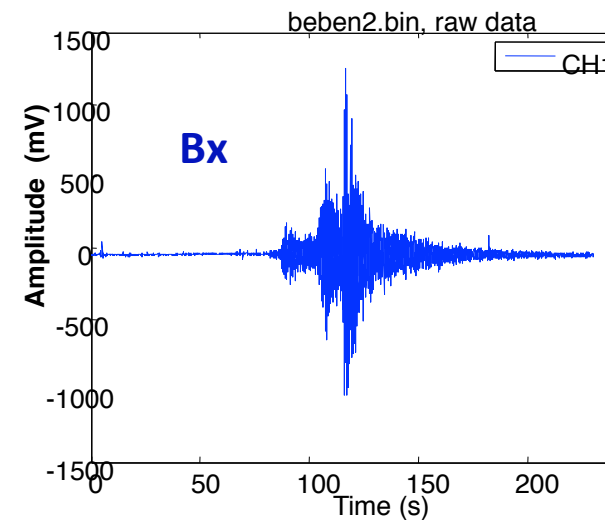
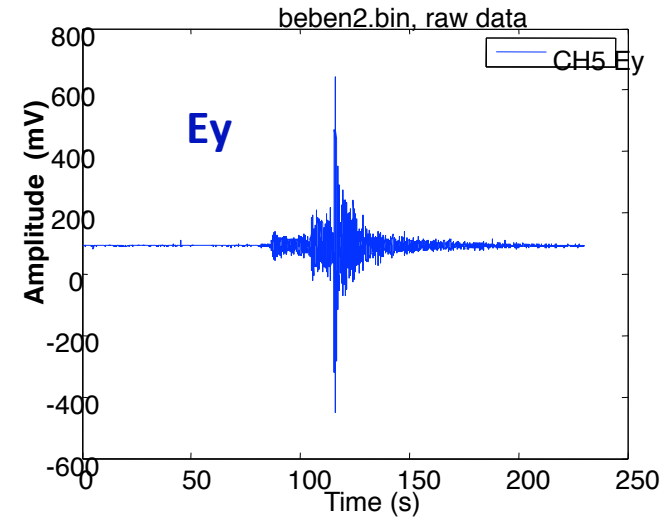
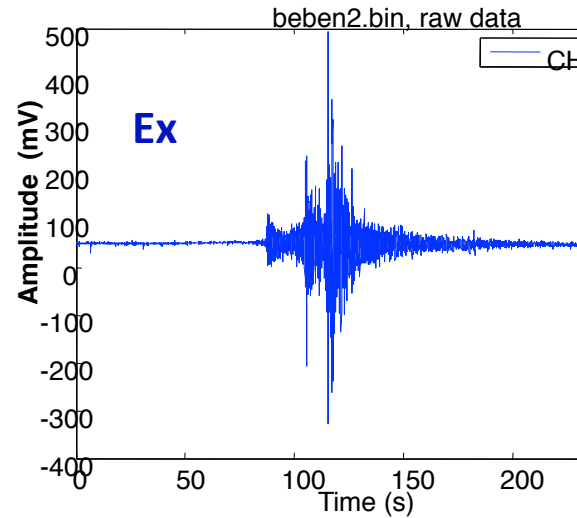
Dimension Parameter



Technology >> parallel sensor test >> MT >> **monitoring**  
**India, Assam: earthquake**



**14 July 2012**  
**magnitude 5**  
**200 km distance**  
**Visible in all**  
**components**





Technology >> parallel sensor test >> MT >> **monitoring**  
**China: Dalian MT setup**

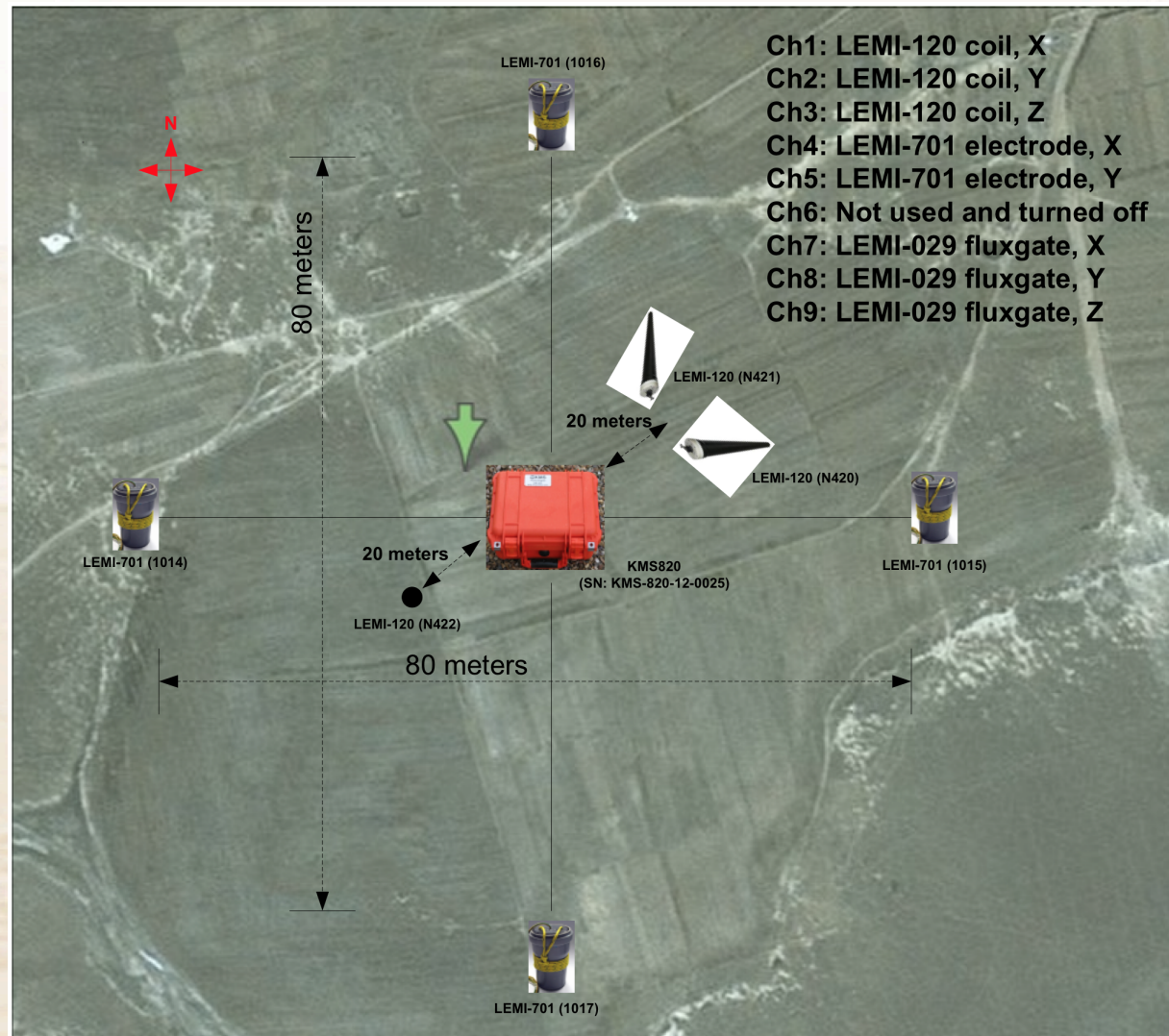


**30 days monitoring  
experiment**

**24 hour recording  
schedule with fixed time  
table for different  
sampling rates &  
recording time**

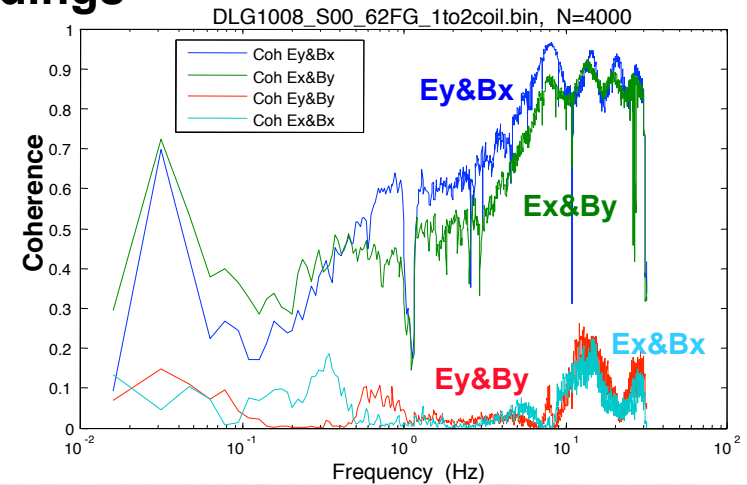
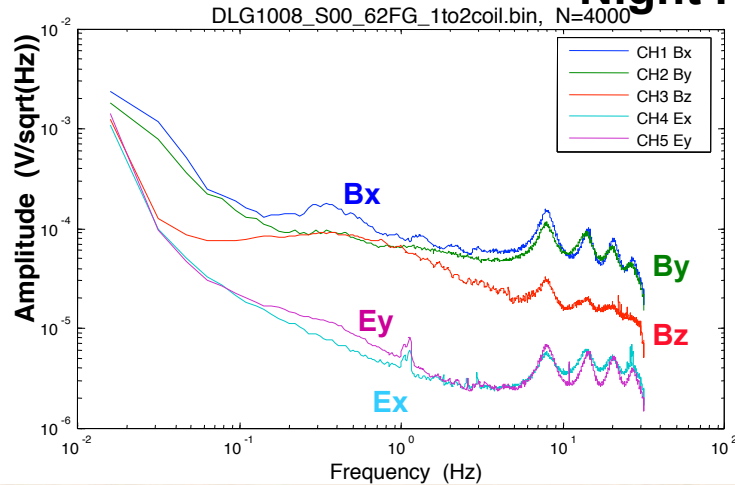
**Daily data collection &  
processing**

**Purpose:  
monitoring performance  
for seismology**

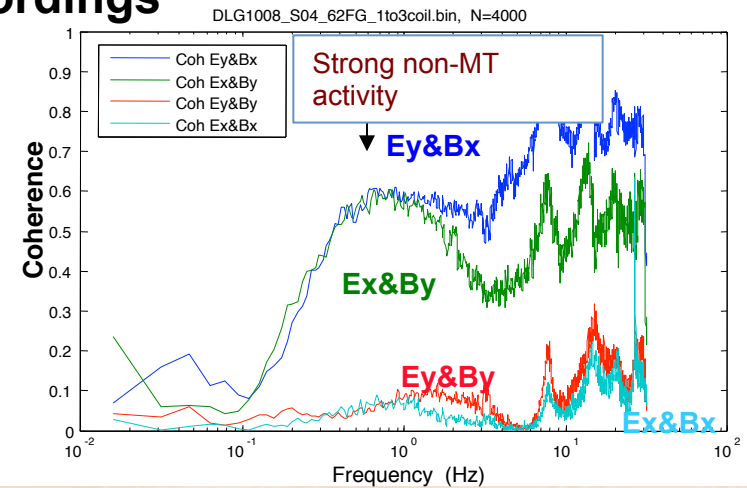
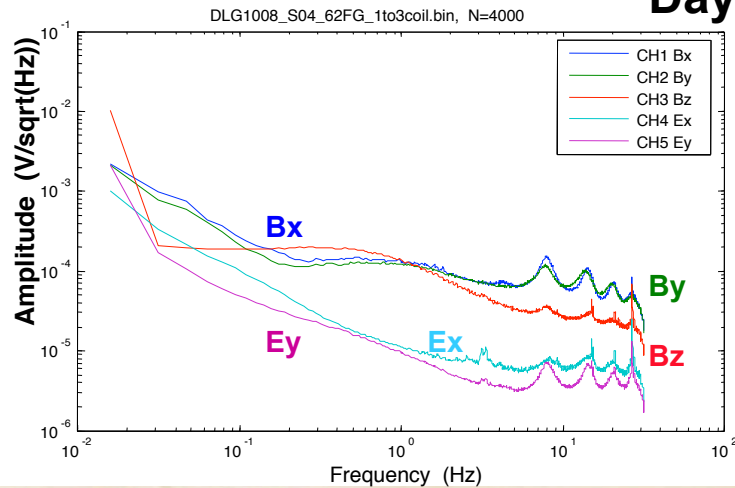




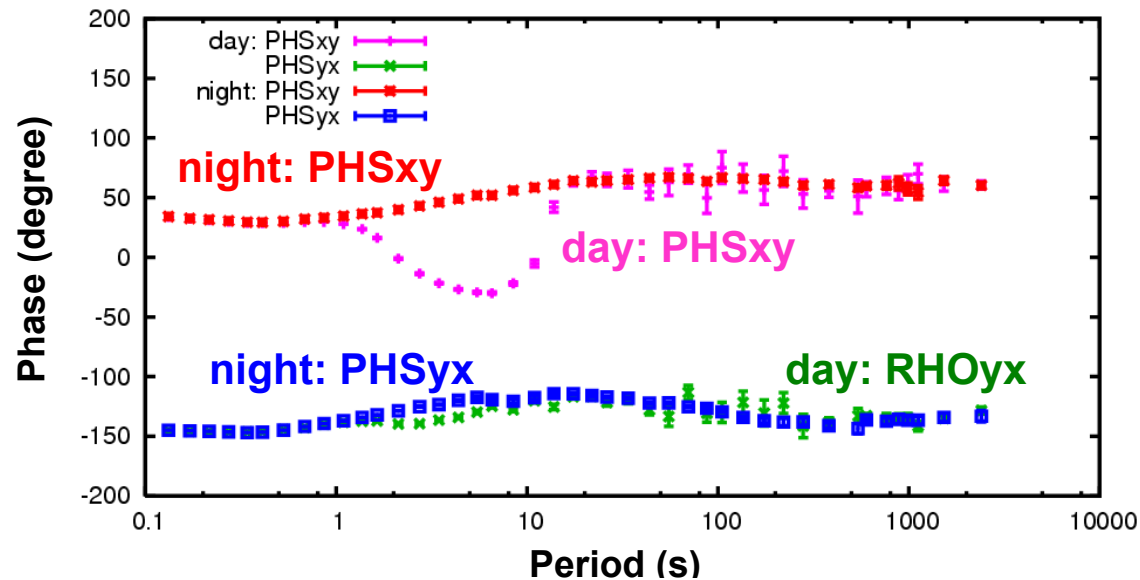
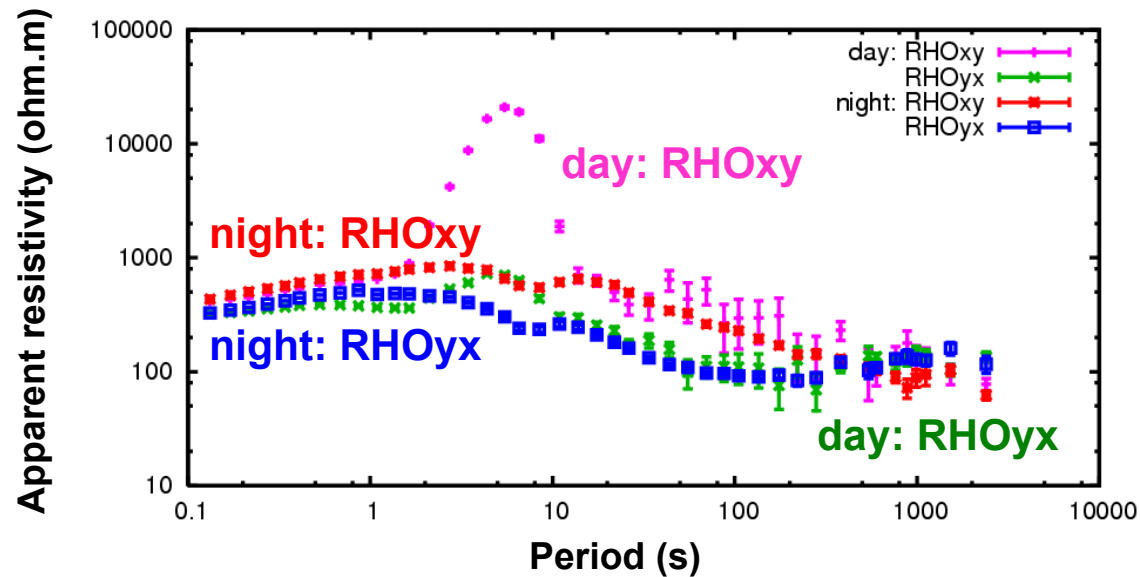
## Night recordings



## Day recordings



Technology >> parallel sensor test >> MT >> monitoring  
**Monitoring: day & night**



Night

22:00 to 6:00

Day

6:00 to 22:00





- KMS820
  - Applied successfully for MT & CSEM (LOTEM)
- Parallel sensor test
  - All induction coils match specification
  - A proper set up with only 2 parallel sensors, short distance
  - Issue EMI coils: strong & variable offset
- Fluxgate magnetometer
  - For periods > 30 s → useful RHOa
  - Phase & tipper
- Monitoring
  - Any suggestions for high coherent cultural noise?



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