



UNIVERSIDAD NACIONAL DE ASUNCION

FACULTAD DE CIENCIAS EXACTAS Y NATURALES

XII JORNADA DE JOVENES INVESTIGADORES

DESARROLLO DE ESTACION DE BAJO COSTO PARA MONITOREO DE CAMPO MAGNETICO
TERRESTRE

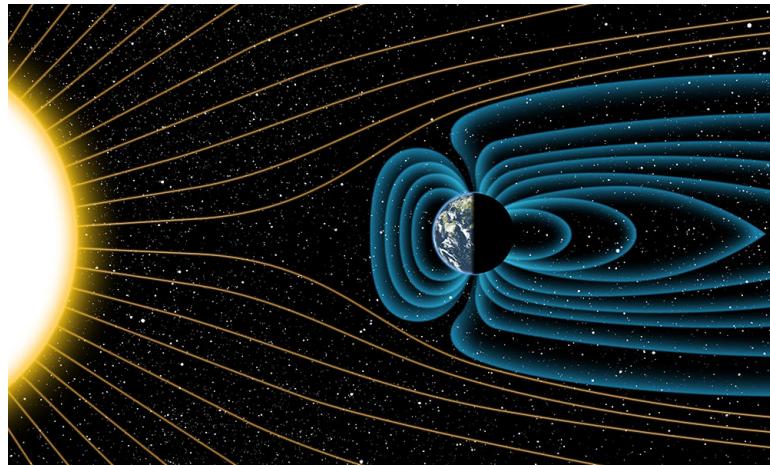
Autores:

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- Gustavo Eduardo Mereles Menesse

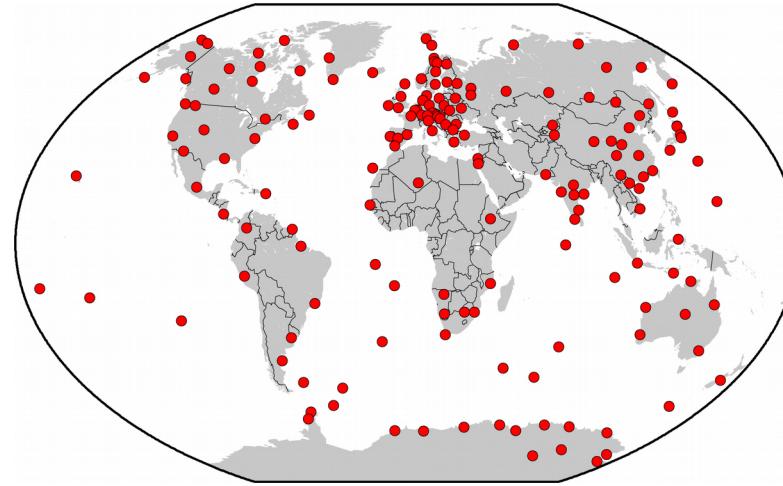
Tutor: Prof. Tomas Rolon

Departamento: Física

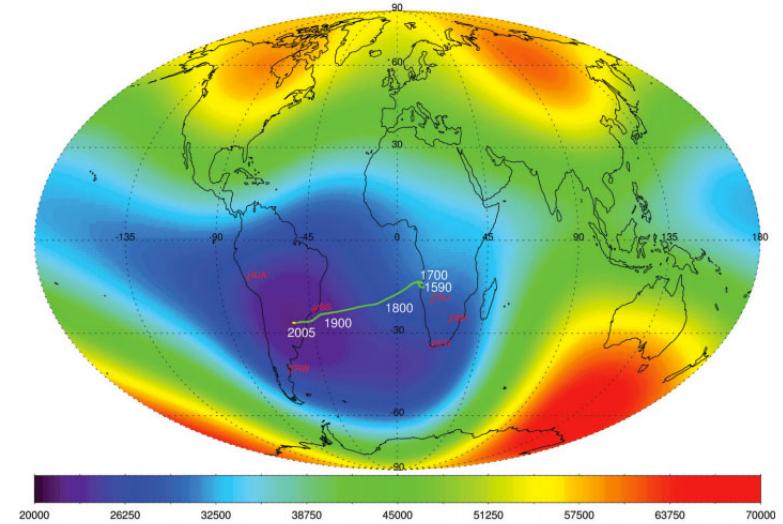
INTRODUCCION



Campo magnético terrestre y clima espacial

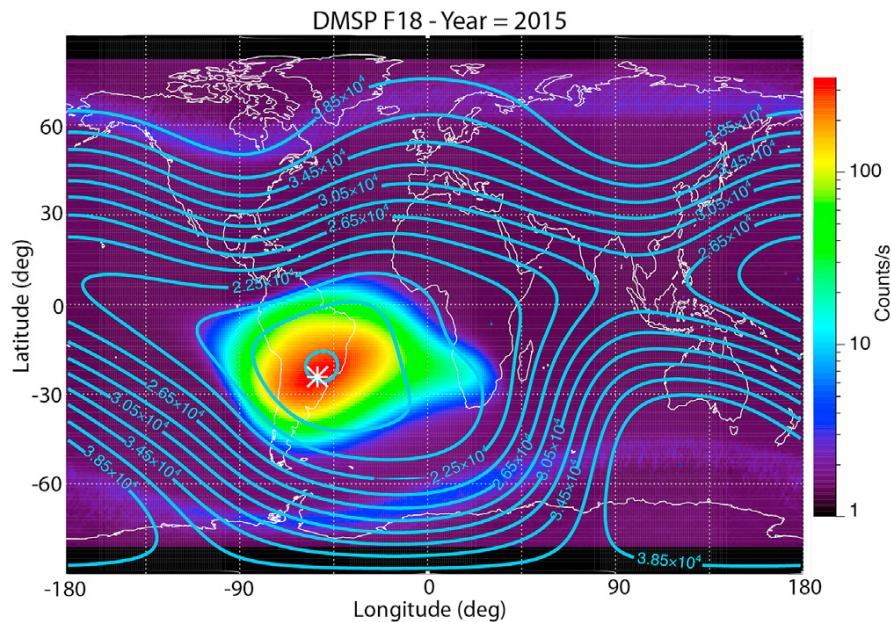


Observatorios a lo largo del globo



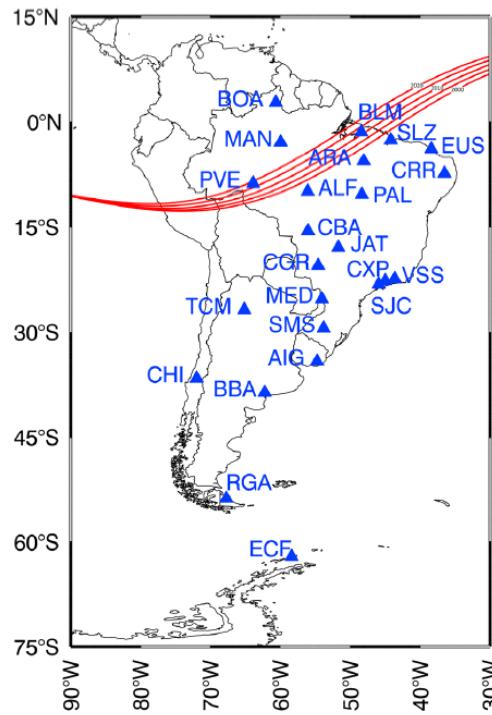
Anomalía del Atlántico Sur (SAA)

PLANTEAMIENTO DEL PROBLEMA



Flujo de partículas que penetra el campo magnético

Fuente: Anderson y Borisov (2017); Denardini et. al (2018).

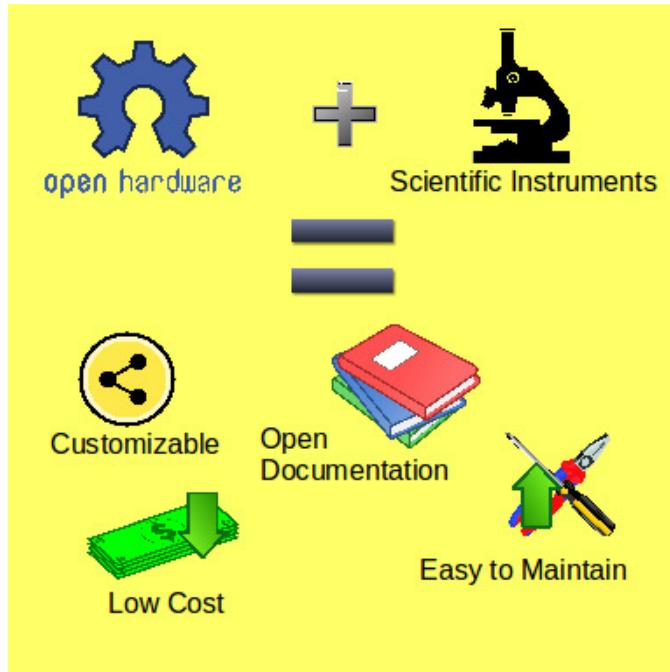


Paraguay no cuenta con un observatorio geomagnético

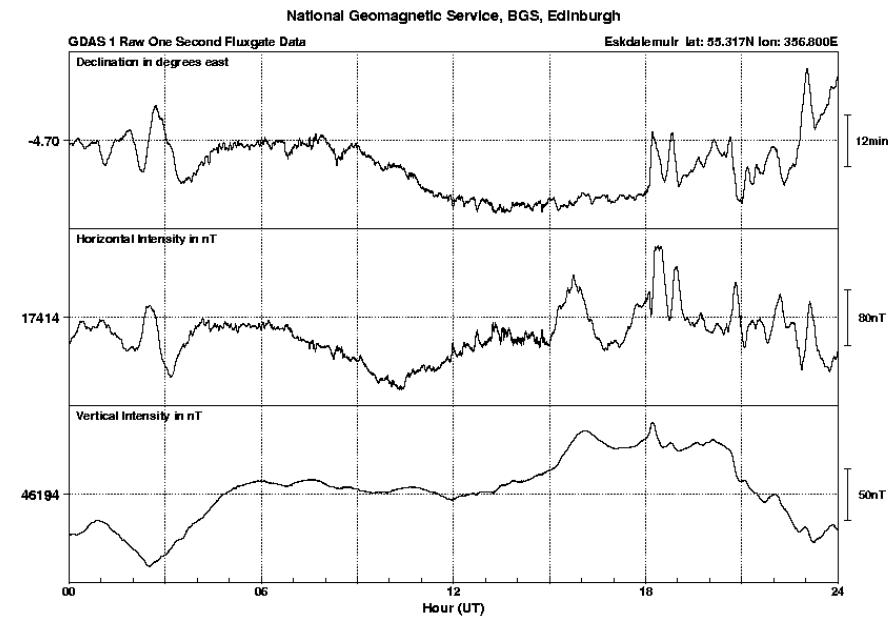


Alto costo de instrumentación científica

JUSTIFICACION



**Experiencia respecto a
hardware y software libre
para instrumentación
científica**



**Datos locales para futuros
trabajos**

OBJETIVOS

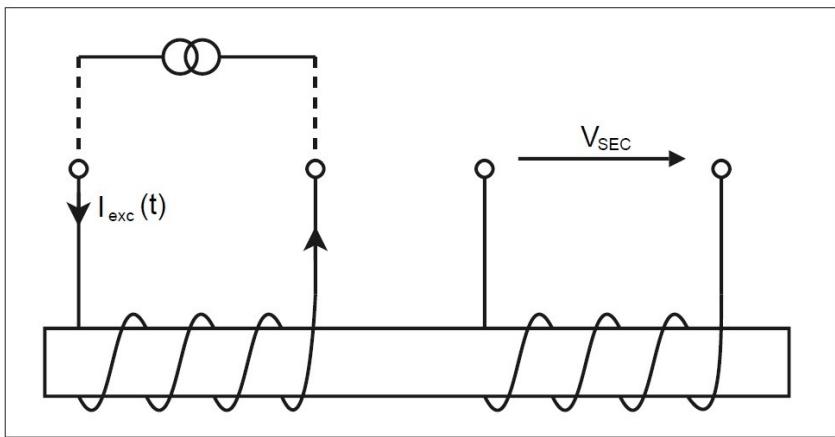
Objetivo General

- Desarrollar una estación de monitoreo del campo magnético terrestre con instrumentación de bajo costo.

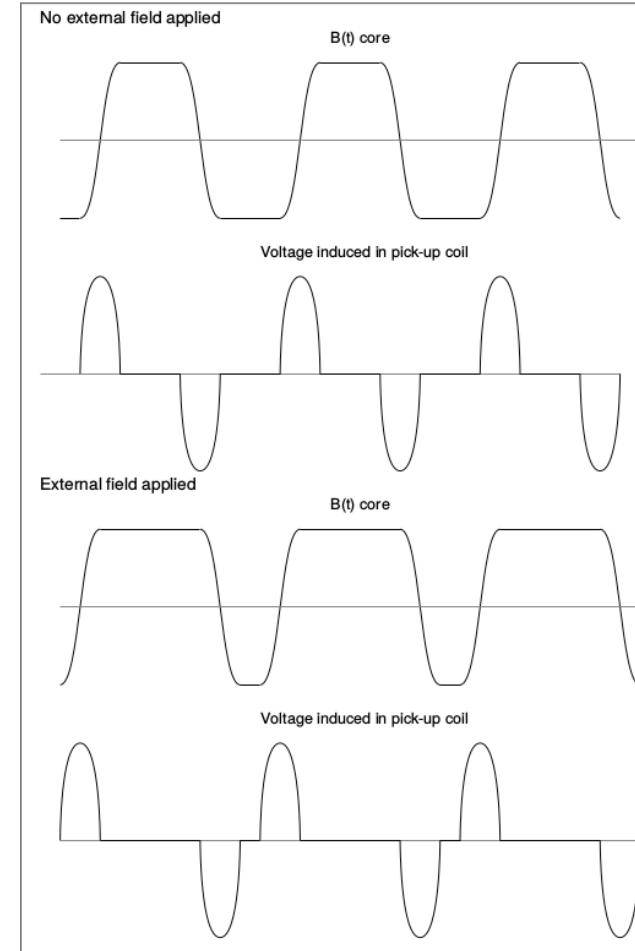
Objetivos Específicos

- Determinar la sensibilidad y precisión del flux-gate magnetometer de bajo costo.
- Diseñar un sistema electrónico de soporte para el sensor utilizando software y hardware libre.
- Validar los datos obtenidos por la estación mediante comparación con datos regionales.
- Determinar la robustez de la estación de monitoreo.

MARCO TEÓRICO



Magnetómetro flux-gate básico



Señal en ambas bobinas

Fuente: Forslund
(2006)

MARCO TEÓRICO



Table 1
Basic Characteristics of the Fluxgate Magnetometers of the Embrace MagNet

Description	Range/values
Total measurement range	$\pm 75,000$ nT
Dynamic range, three selectable	± 250 , 1,000, and 2,500 nT
Maximum resolution	0.1 nT
Accuracy	0.25%
Orthogonality	<0.5°
Offset at 25°C, 1 atm	<1 nT
Zero drift	<0.1 nT/°C
Operating temperature	-20°C to +75°C

Specifications

Analog output: ± 10 V
 Dynamic range: User specified
 Resolution: 0.1 nT
 Compensation field range: +/- 64 000 nT
 Compensation field steps: 150 nT
 Misalignment of sensor axis: < 2 mrad
 Long time drift: < 3 nT/year
 Temp. coeff. of sensor: < 0.2 nT/°C
 Temp. coeff. of electronics: < 0.1 nT/°C
 Resolution of temperature: 0.1 °C
 Band pass: DC to 1 Hz

Spec. of optional suspension

Range of compensation: $\pm 0.5^{\circ}$
 Factor of compensation: > 200

General information

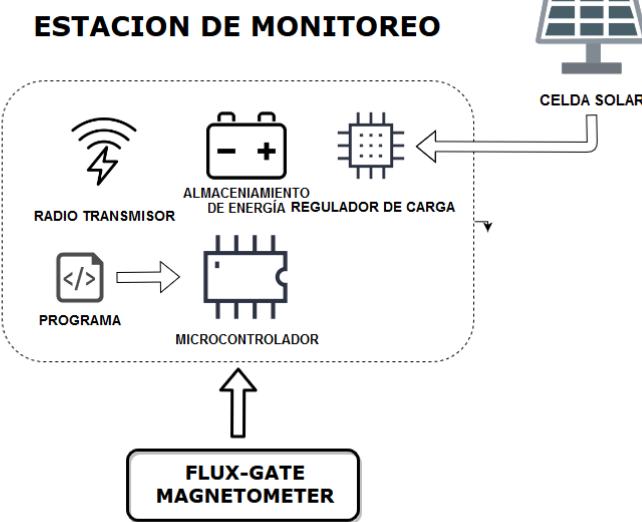
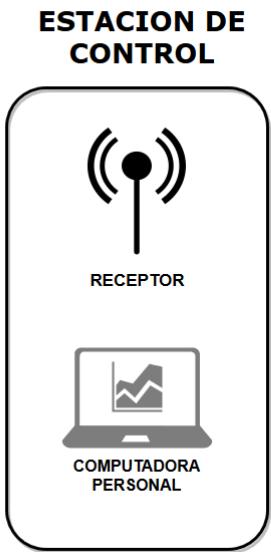
Size of sensor: 190 x 190 x 190 mm
 9.5 kg
 Size of suspended sensor: 250 x 250 x 550 mm
 20 kg
 Size of electronics: 160x90x360 mm
 3.0 kg
 Power requirements: 230 VAC, 3W
 Operating temperature: 0 to 60°C Optional
 Optional power supply: 10-18 VDC, 3 W

Optional digital output:
8 ch /16 bit AD AM AD-converter

Danish Meteorological Institute Solar-Terrestrial Physics Division

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 E-mail: or@dmi.dk

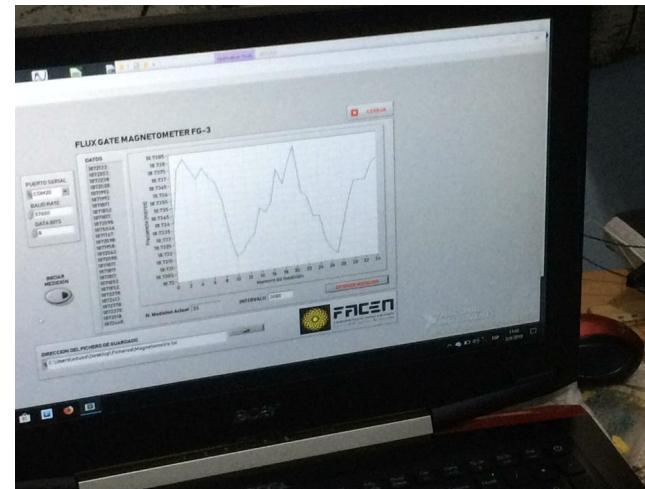
IDEA



Diseño preliminar de la estación

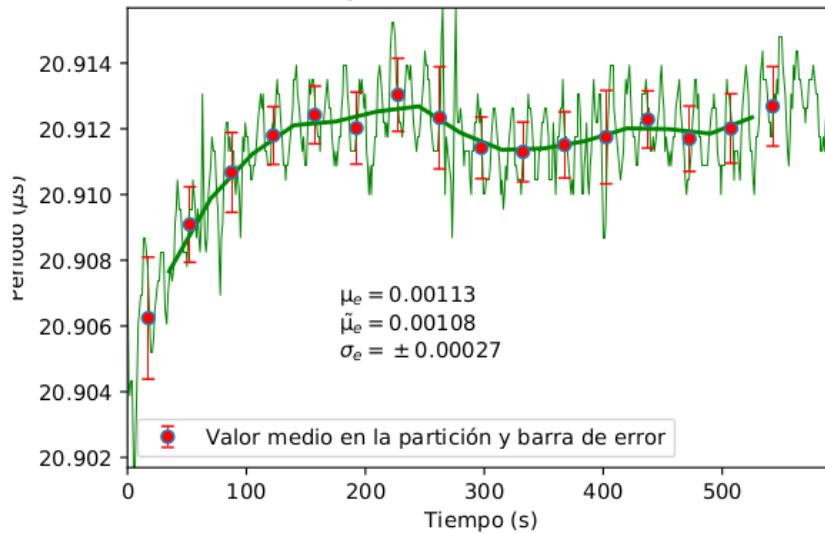
Selección del sensor y componentes

Montaje experimental para calibración de sensores y determinación de sensibilidad

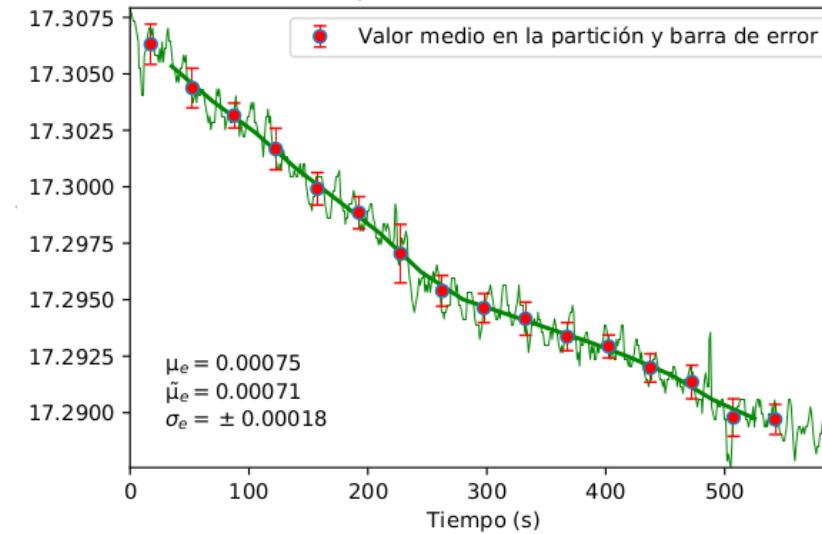


Obstáculo: Reducción del ruido (campos externos, electrónica, otros)

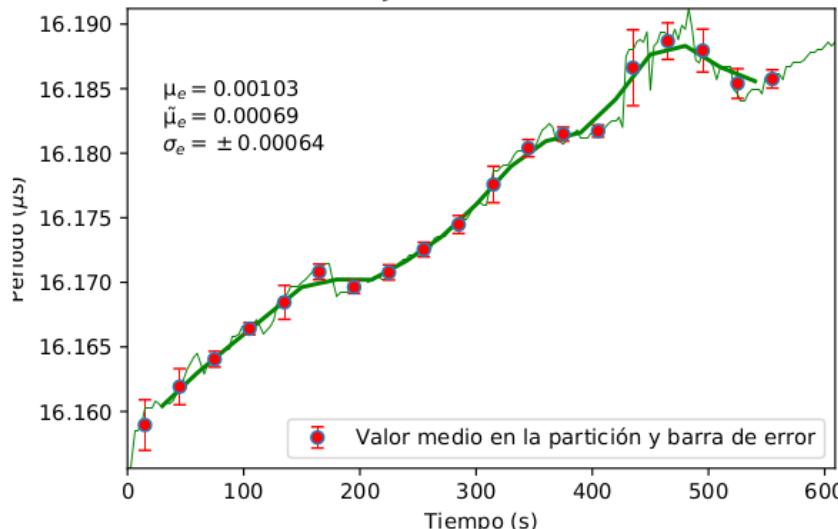
SIN BLINDAJE CON FUENTE CONVENCIONAL



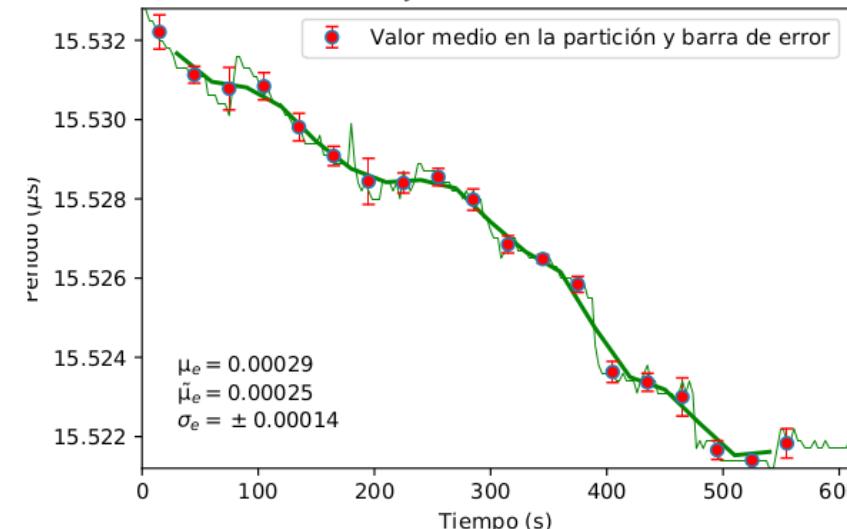
CON BLINDAJE CON FUENTE CONVENCIONAL



SIN BLINDAJE CON FUENTE PRECISION



CON BLINDAJE CON FUENTE PRECISION



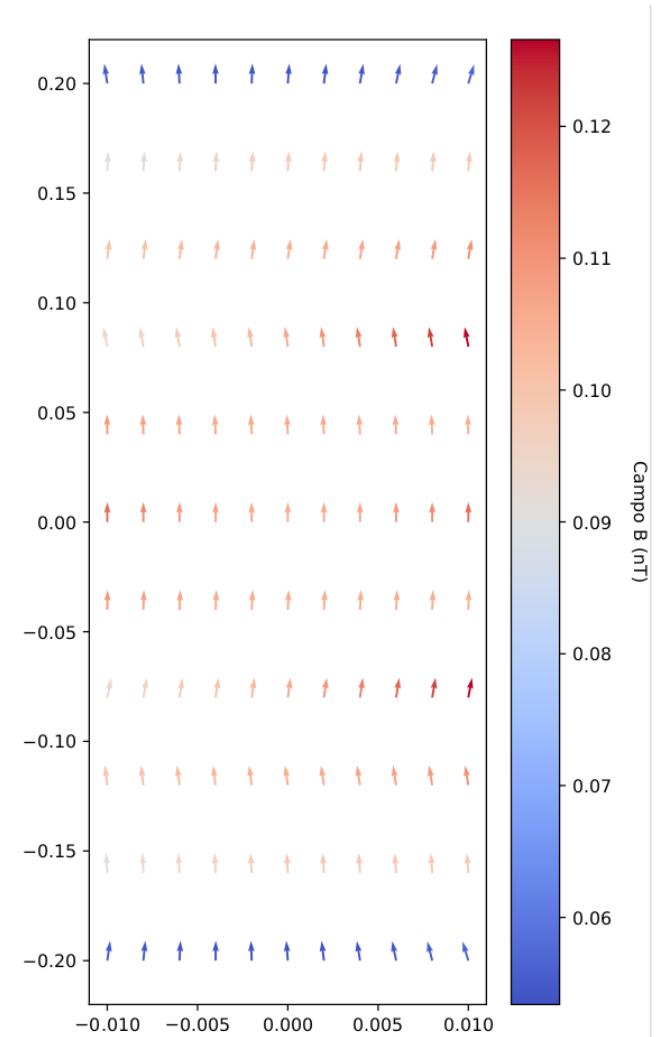
Campo generado por la bobina helicoidal

Geometría bobina: 40cm largo, 5 cm ancho, 2mm espaciamiento

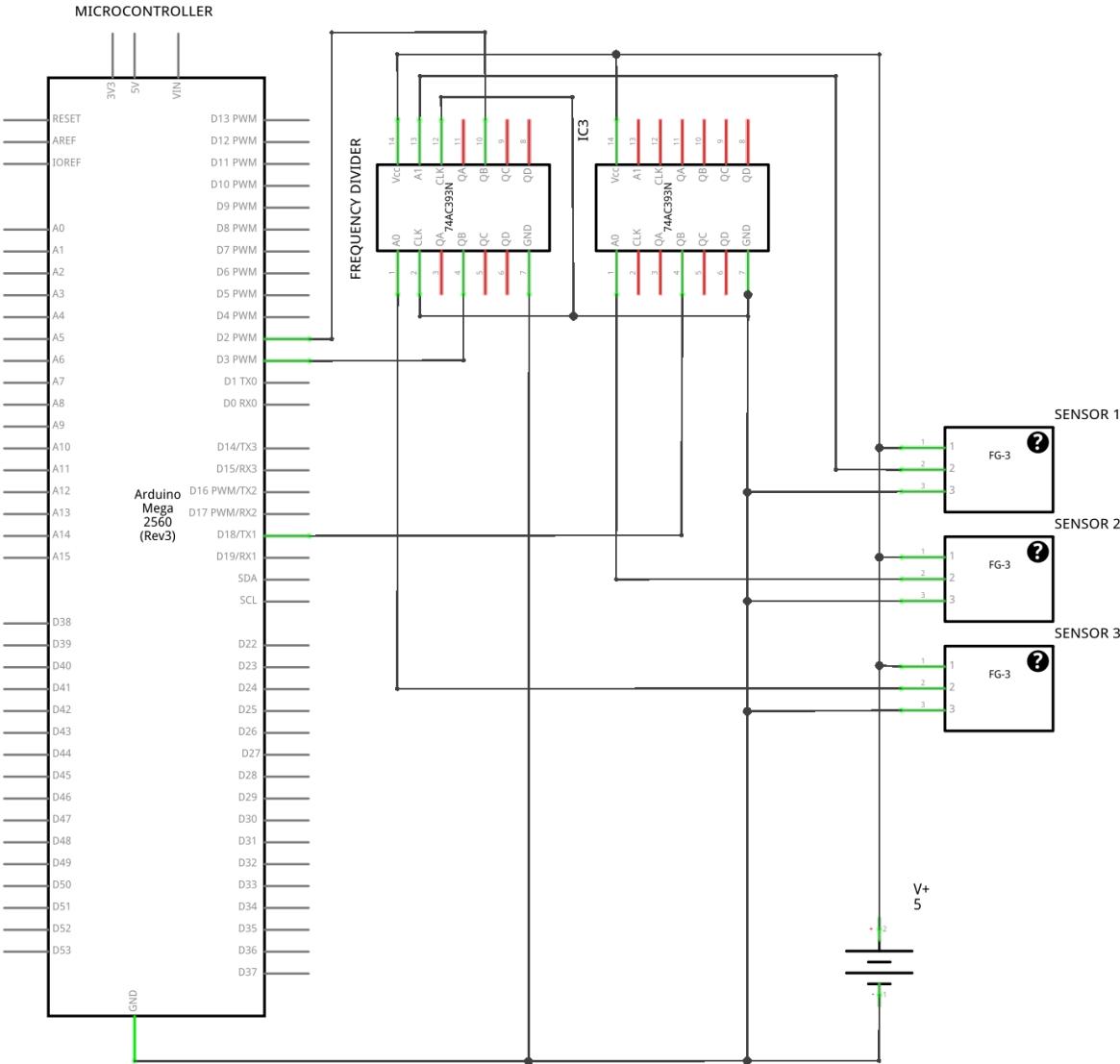
$$\begin{aligned} & I\mu_0 \int_{-200\pi}^{200\pi} \left(-\frac{4\pi^2(R(a\phi-2\pi z)\cos(\phi)-a(R\sin(\phi)-y))}{((a\phi-2\pi z)^2+4\pi^2((-R\sin(\phi)+y)^2+(-R\cos(\phi)+x)^2))^{\frac{3}{2}}} \right) d\phi \hat{\mathbf{i}}_N \\ & + \left(\frac{I\mu_0}{4\pi} \int_{-200\pi}^{200\pi} \left(-\frac{4\pi^2(R(a\phi-2\pi z)\sin(\phi)+a(R\cos(\phi)-x))}{((a\phi-2\pi z)^2+4\pi^2((-R\sin(\phi)+y)^2+(-R\cos(\phi)+x)^2))^{\frac{3}{2}}} \right) d\phi \right) \hat{\mathbf{j}}_N \\ & + \left(\frac{I\mu_0}{4\pi} \int_{-200\pi}^{200\pi} \left(-\frac{8\pi^3 R (-R+x\cos(\phi)+y\sin(\phi))}{((a\phi-2\pi z)^2+4\pi^2((-R\sin(\phi)+y)^2+(-R\cos(\phi)+x)^2))^{\frac{3}{2}}} \right) d\phi \right) \hat{\mathbf{k}}_N \end{aligned}$$

Integración por métodos numéricos, quadratura gauss scipy

Con error menor a 10^{-18} T



SISTEMA TEMPORARIO TOMA DE DATOS



Script Python

```

[43]: import serial, time, csv, serial.tools.list_ports

import time
global num
num = 0
N = 2
file = "corriente_FG3_s4_Curval"
intens = 0.05e-3
pres = 0.05e-3
Archivo = "Datos_Ahorras.csv"

def escribir(dts):
    with open(Archivo, 'a') as csvFile:
        ahora = time.strftime("%c")
        T[ahora]
        I[intens]
        P[pres]
        #print(ahora)
        dts.append(dts[1, axis=0])
        dts.append(dts[2, axis=0])
        dts.append(dts[3, axis=0])
        print(dts)
        writer = csv.writer(csvFile, delimiter='t', lineterminator='\n')
        writer.writerow(dts)
        csvFile.close()

ports = list(serial.tools.list_ports.comports())
for p in ports:
    print(p)
arduino = serial.Serial('/dev/ttyACM0', 115200, timeout=.1)

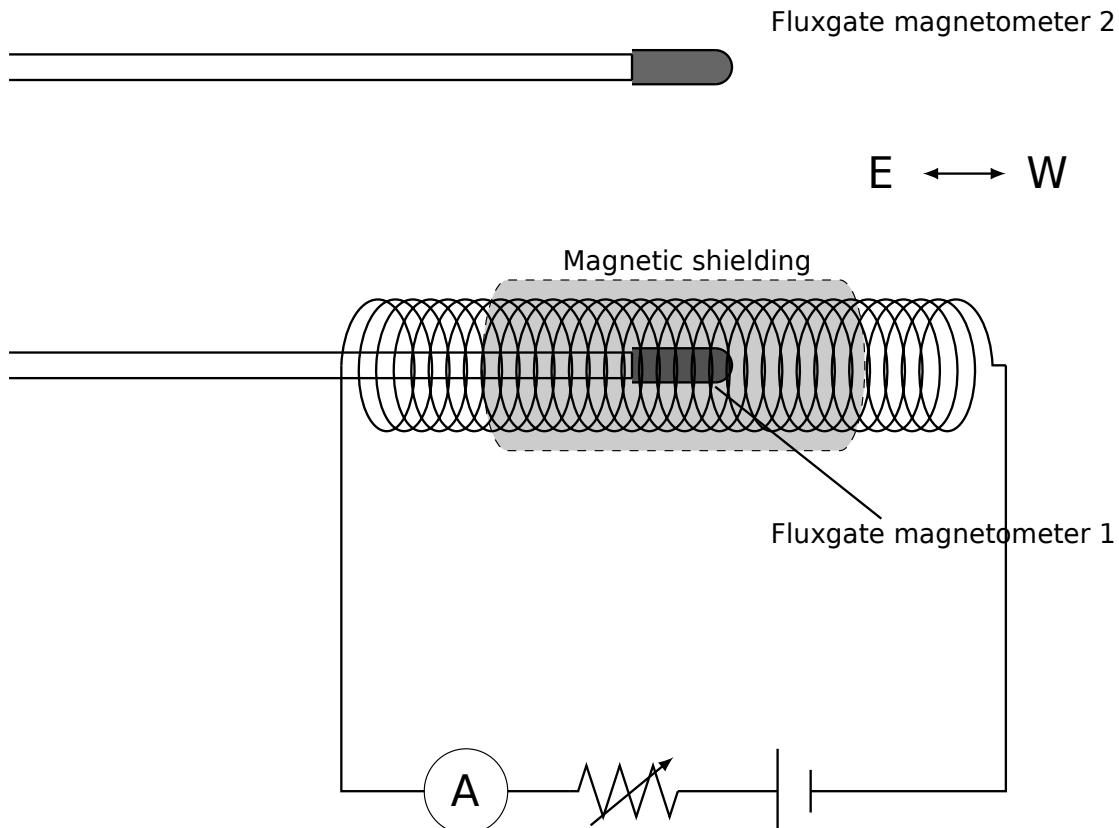
sep=[]
DAT=[]
n=0

while num < N:
    if n==0:
        arduino.write('M'.encode())
        n=1
    data = arduino.readline()
    if data:
        dts=(data.decode().strip().split(' '))
        dts = [float(x) for x in dts]
        print(dts)
        if dts[0] == '0' or dts[0] == '0.0':
            print("Descartado")
        else:
            num = num + 1
            escribir(dts)
            dts=[]
    else:
        if n>0:
            n+=1
            time.sleep(.1)
        else:
            n=0

arduino.close()
/dev/ttyACM0 - Arduino Mega 2560
0
[ 257 '18277524' '16344142' '0.0' '5e-05' 'Fri Aug 2 15:21:05 2019']

```

Montaje experimental para curva de calibración



Propuesta

Sin campo creado

$$Xe(0) = Xt + Xzero$$
$$Xi(0) = Xt + Xzero - Xb$$

$$Xb = Xe(0) - Xi(0)$$

Con campo creado

$$Xi = Xt + Xzero + Xc - Xb$$

Donde,

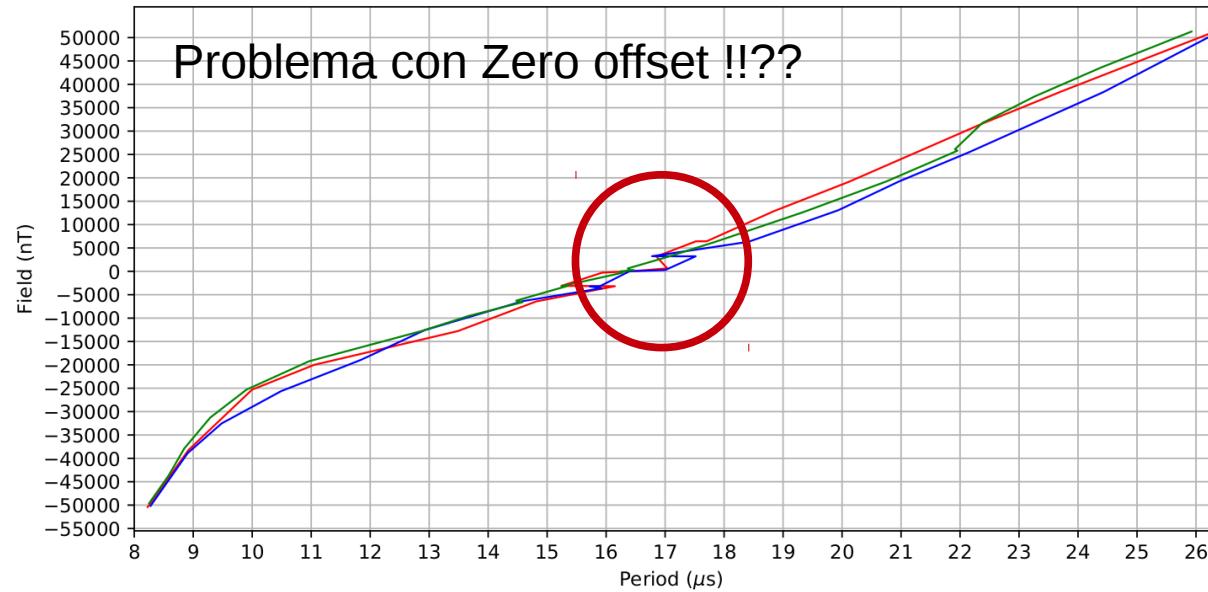
Xe = Periodo sensor externo

Xi = Periodo sensor interno

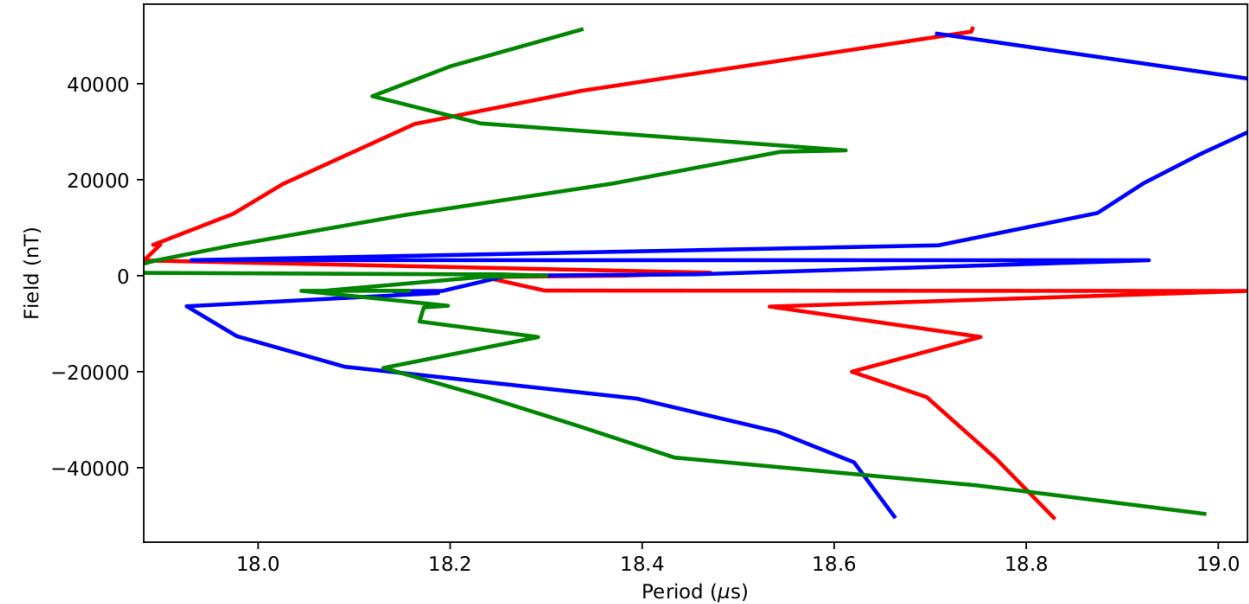
Xb = Diferencia debido a blindaje

Xc = Campo creado por la bobina

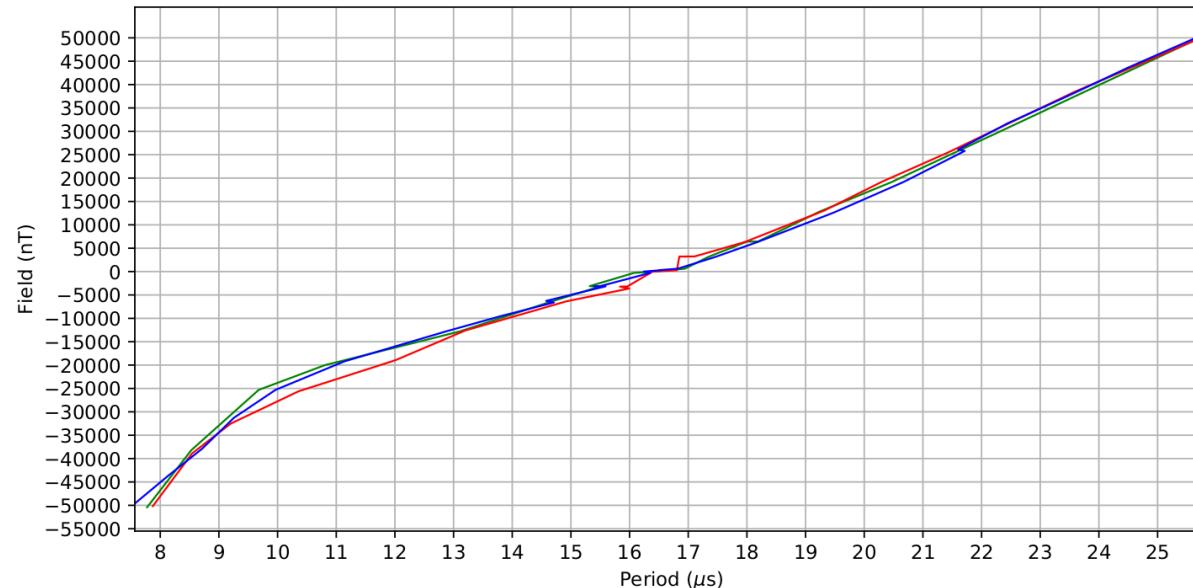
INSIDE

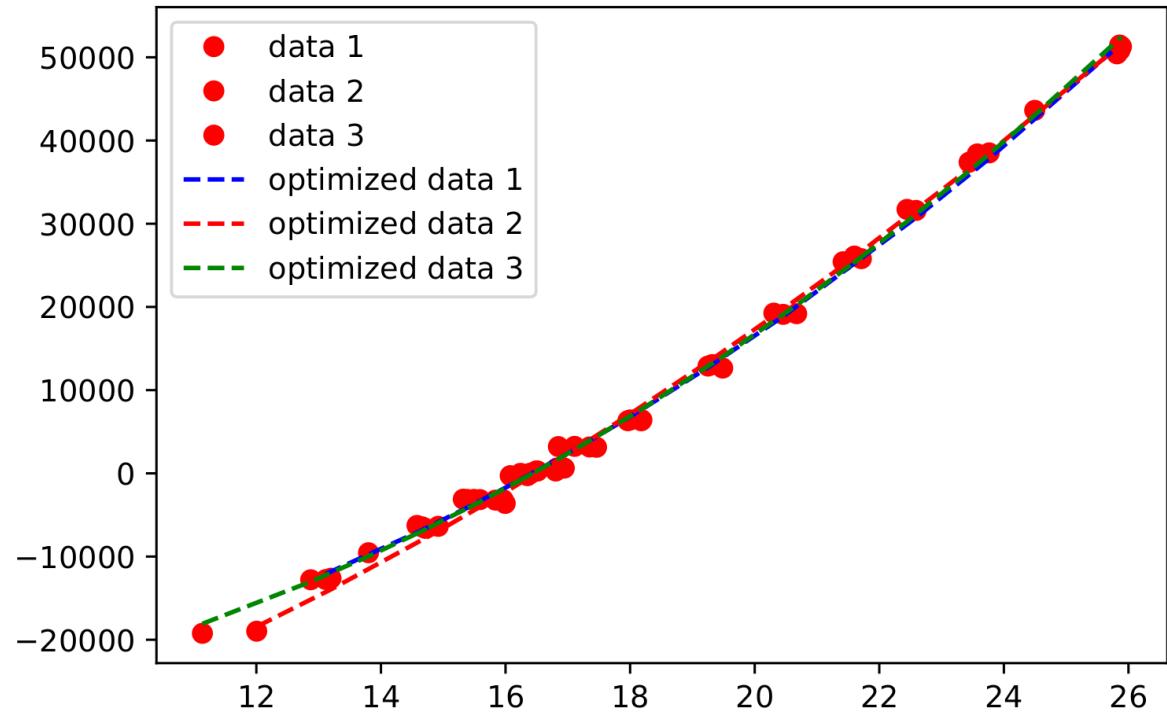
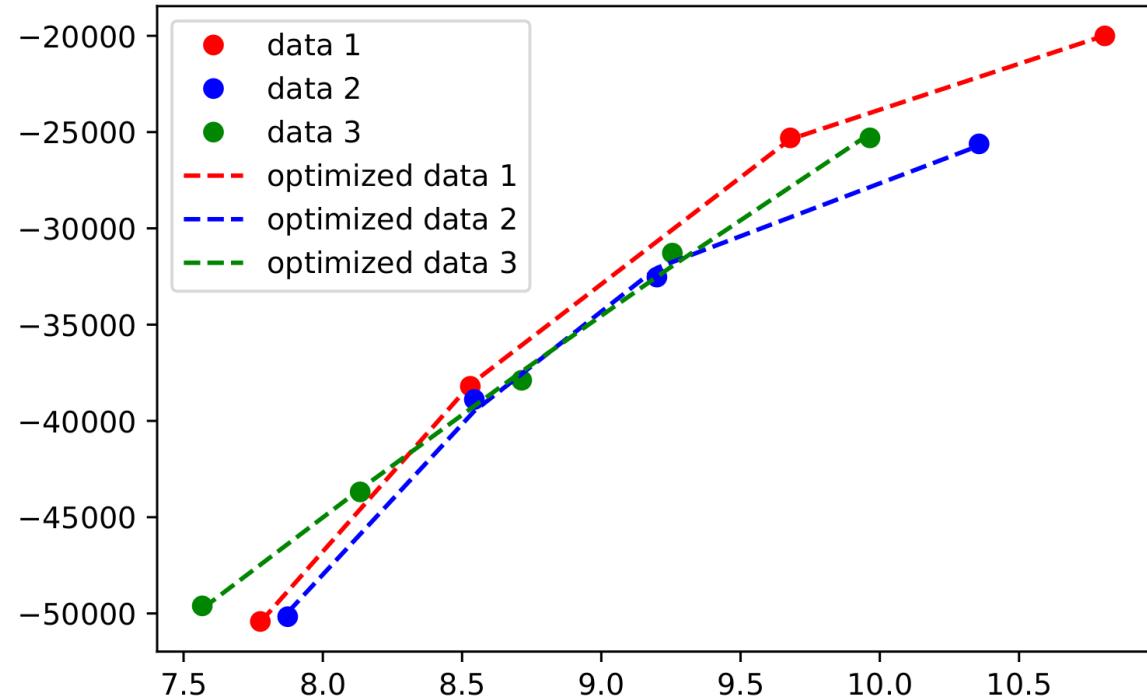


OUTSIDE

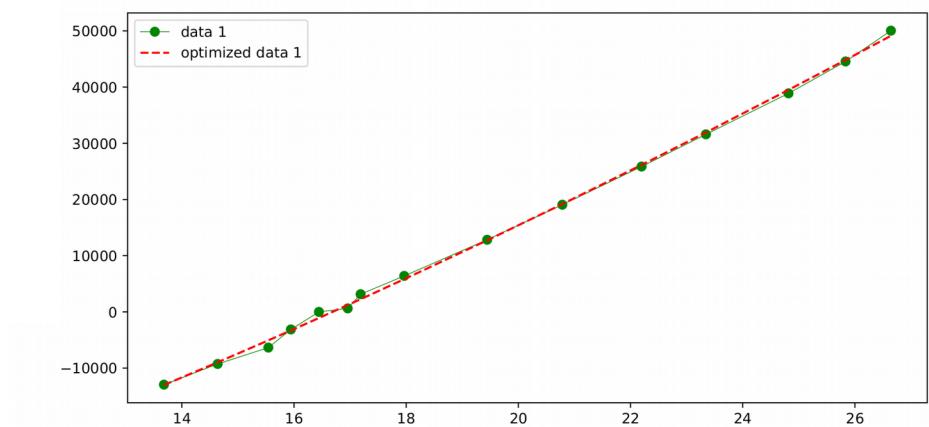
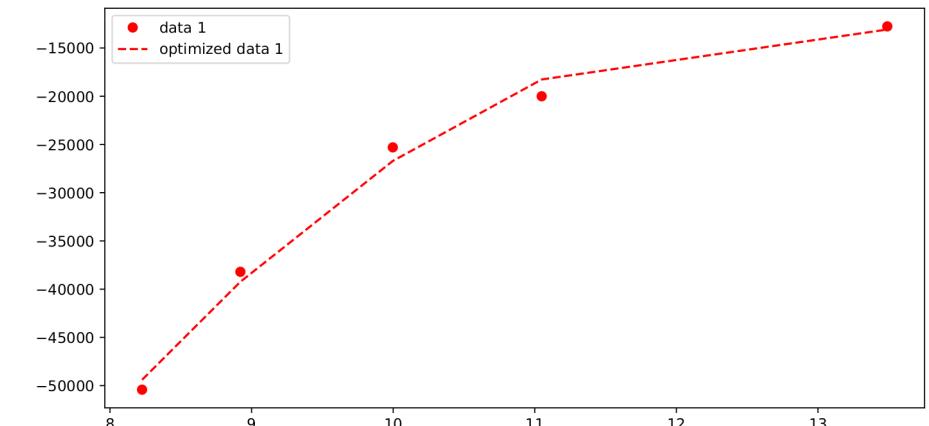
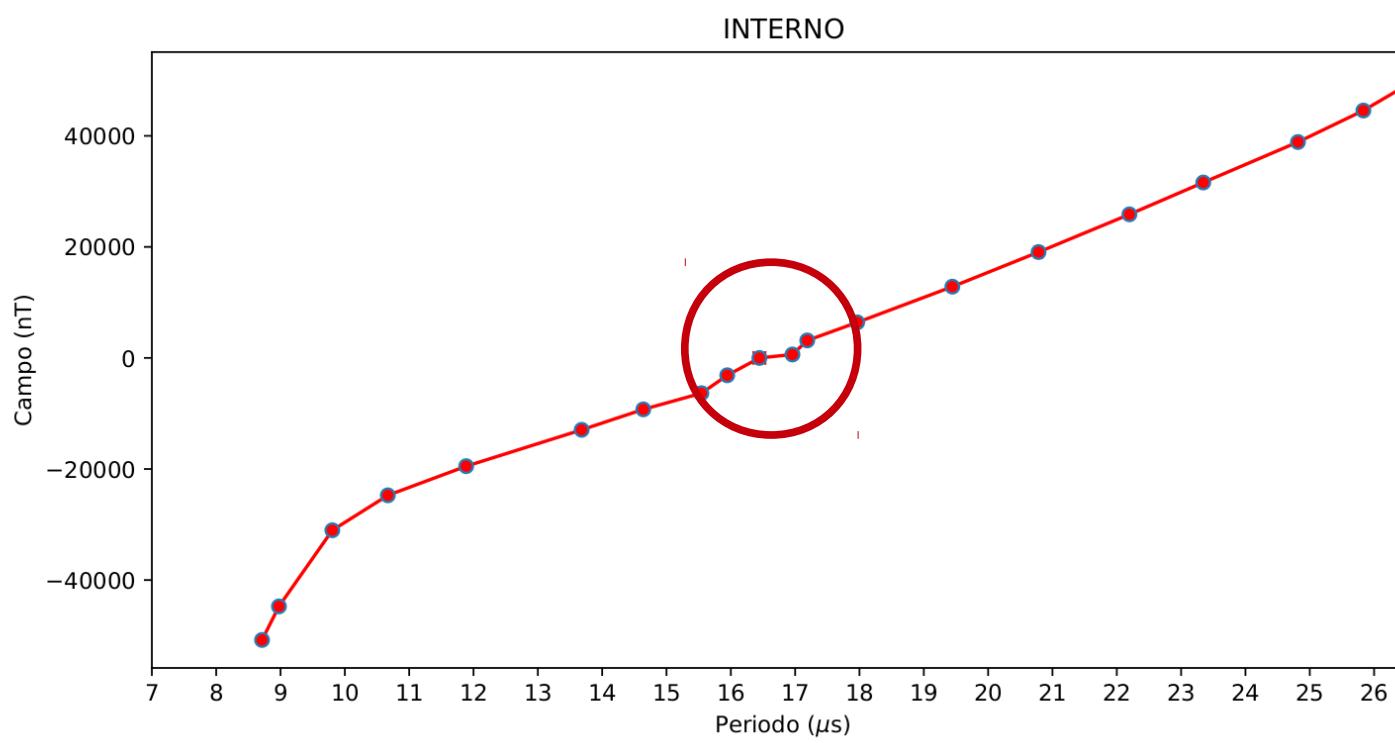


INSIDE

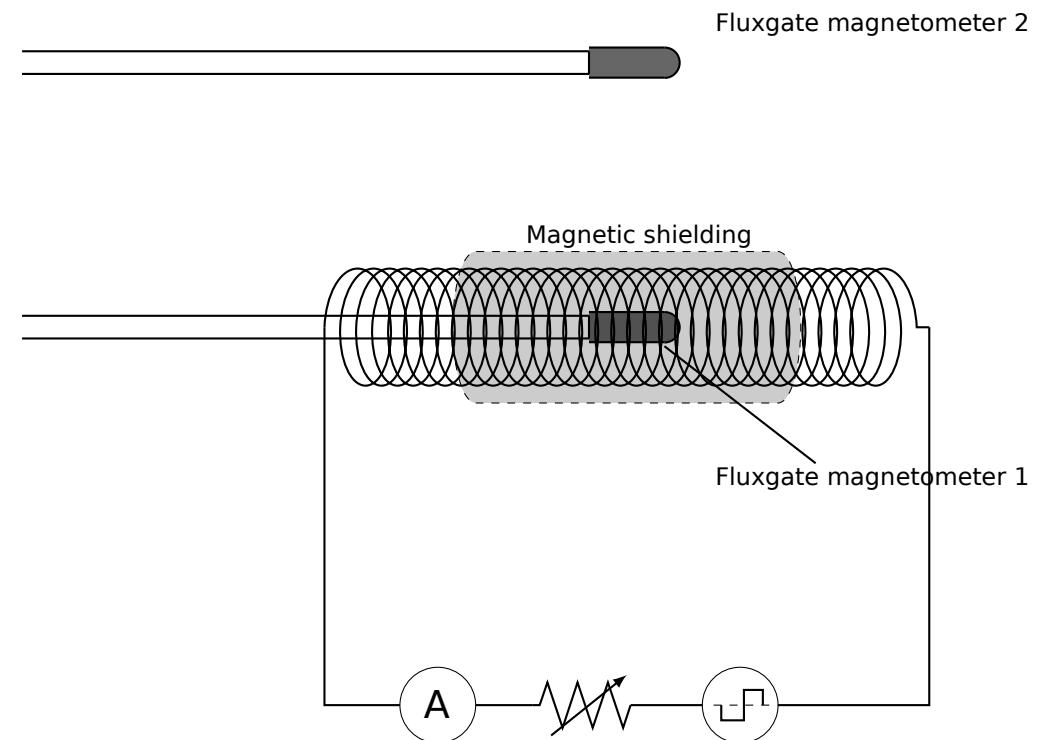
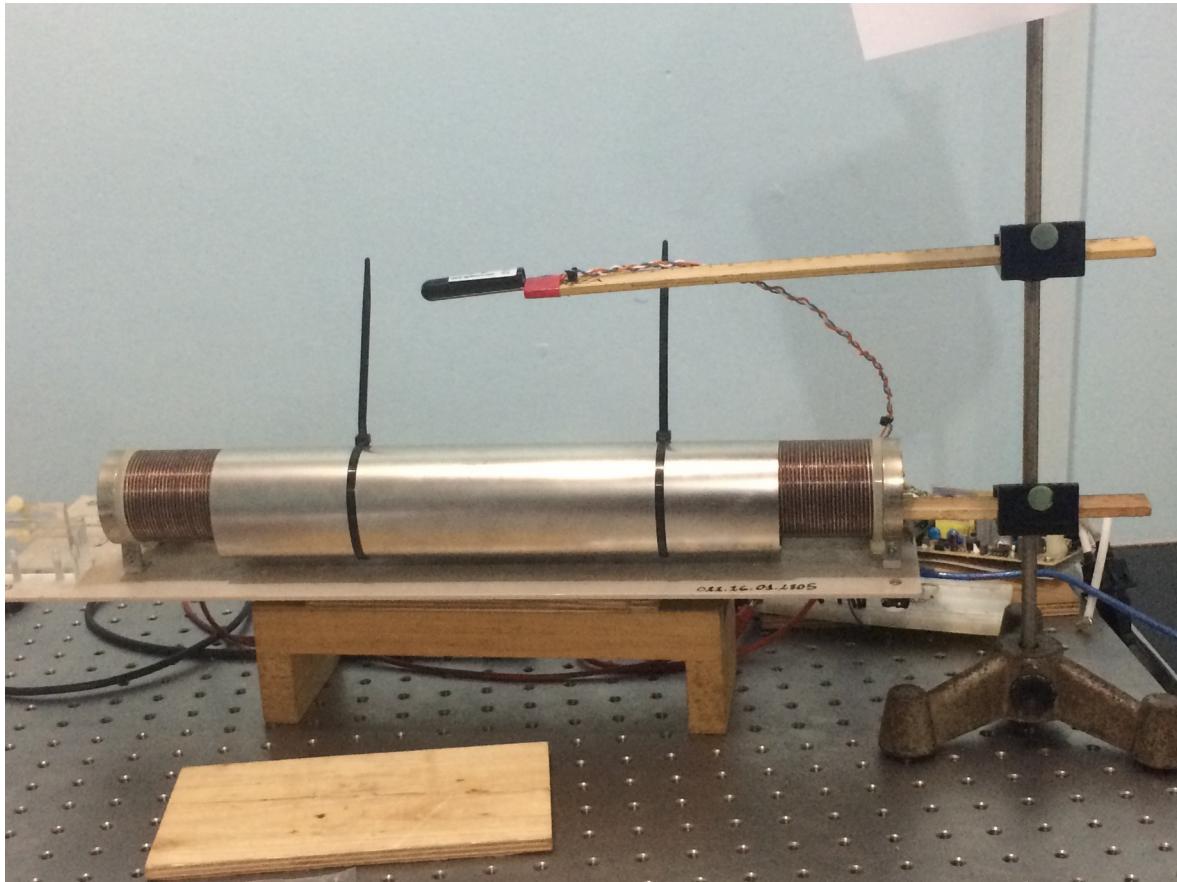




No obstante!!! En otro momento con la misma metodologia, en el mismo lugar de trabajo



Montaje experimental propuesto para determinación de sensibilidad del sensor



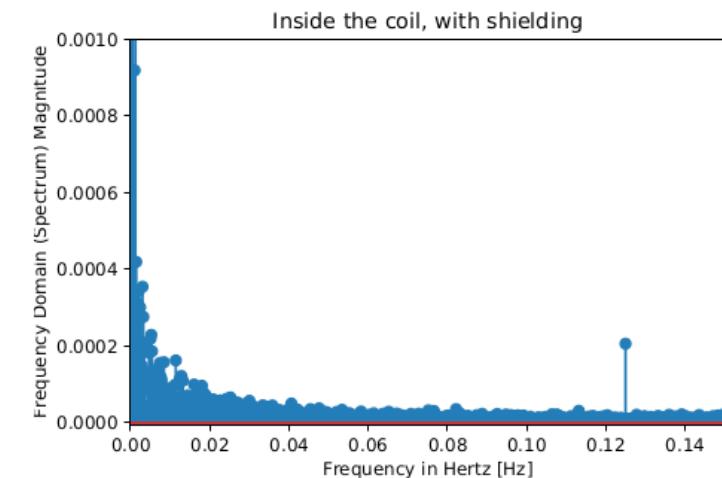
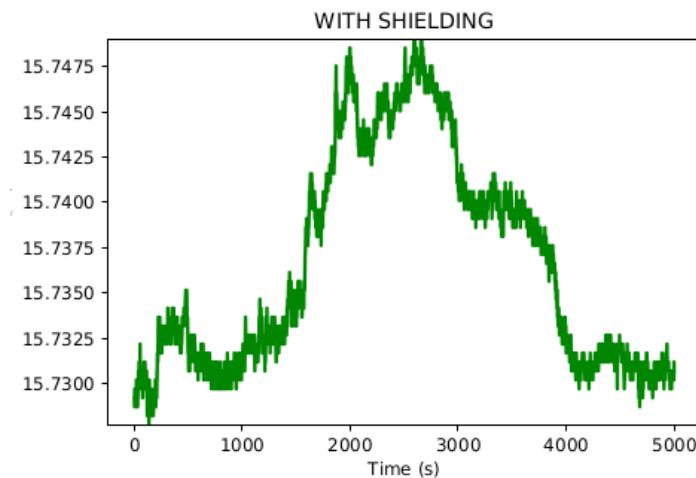
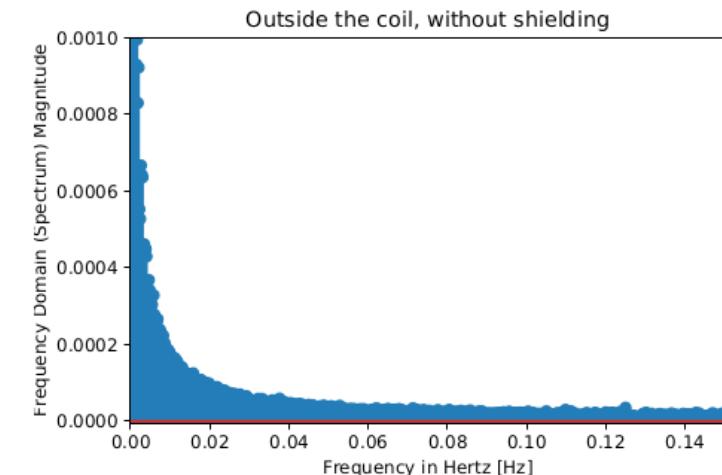
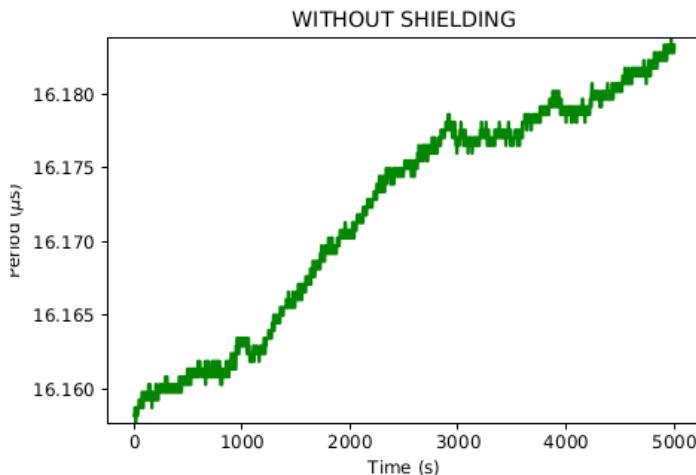
Esquema montaje

Con una onda cuadrada de frecuencia 0.125 Hz, oscilación de 2 microAmpere

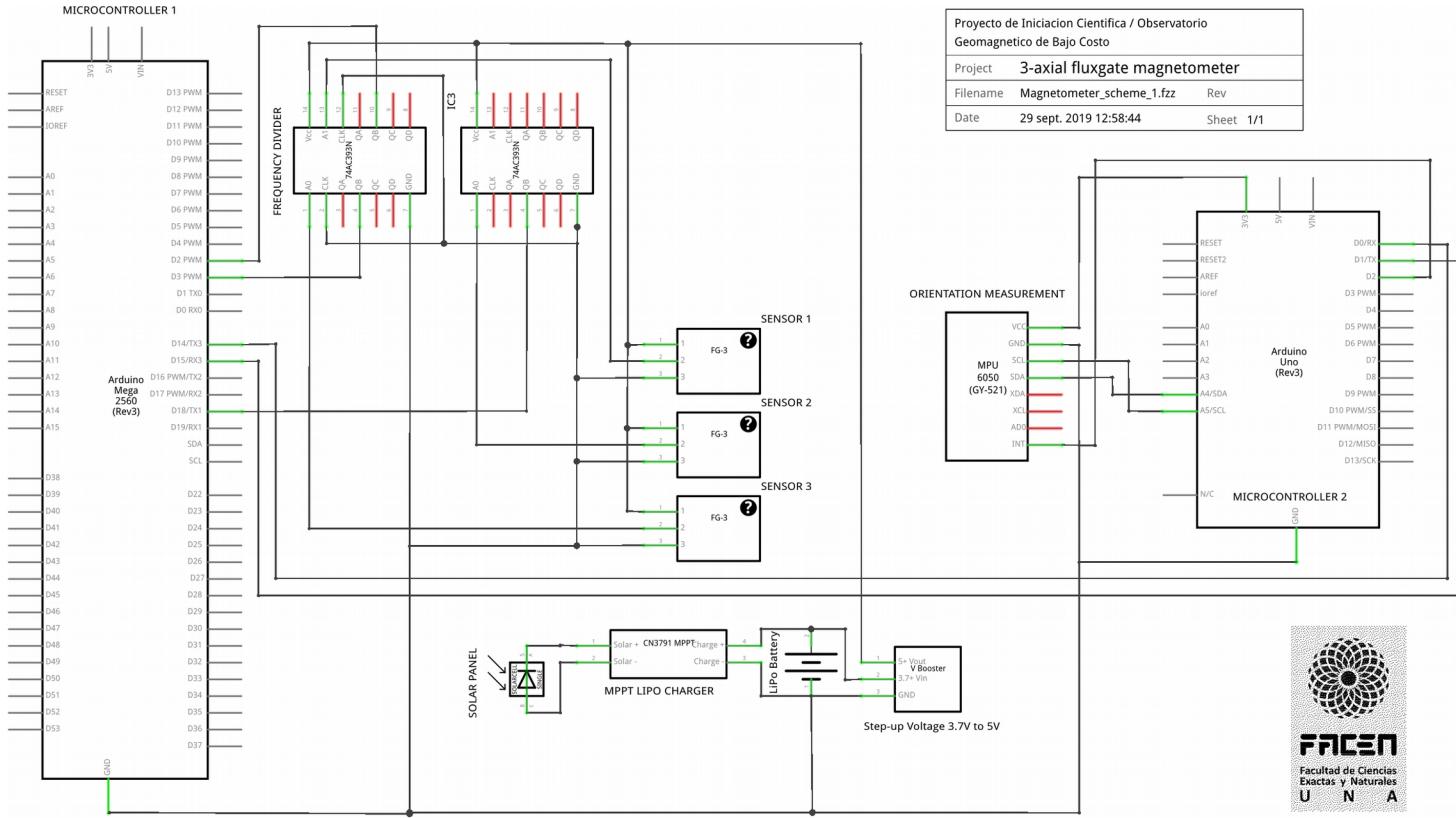
La variación de campo según el modelo, para una variación de 2 microAmpere es de 0.6nT

La amplitud en la frecuencia es de 0.0002 microsegundos

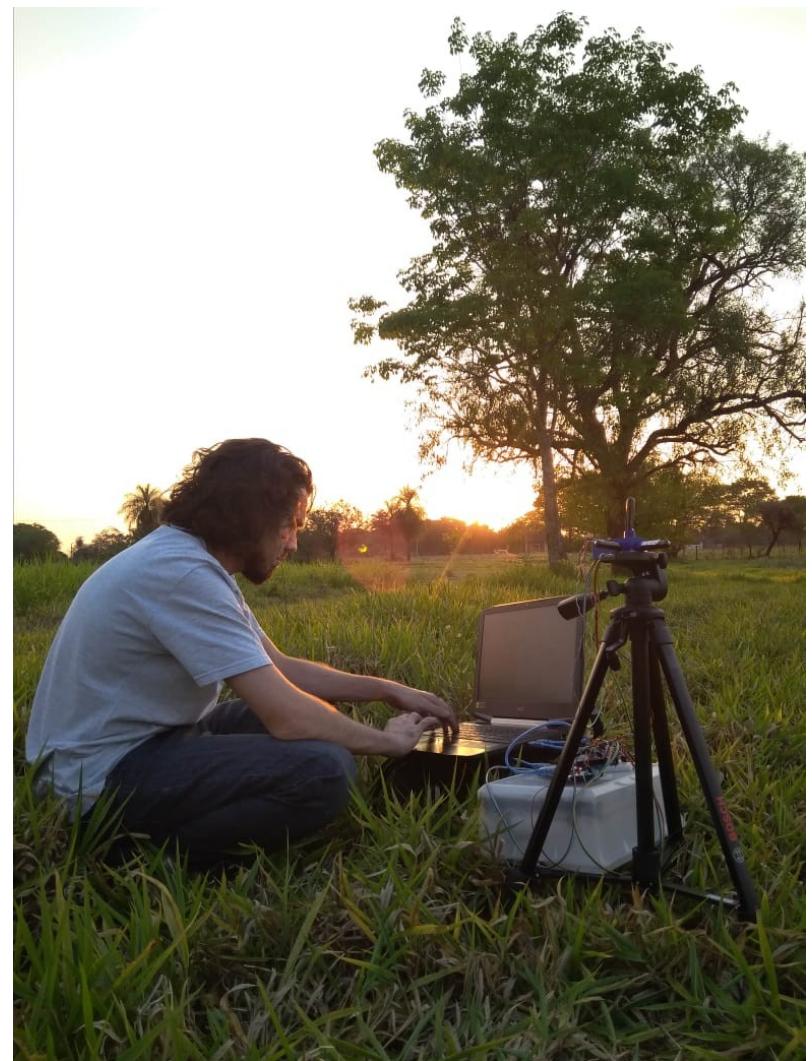
Corresponde a 0.8nT aproximadamente

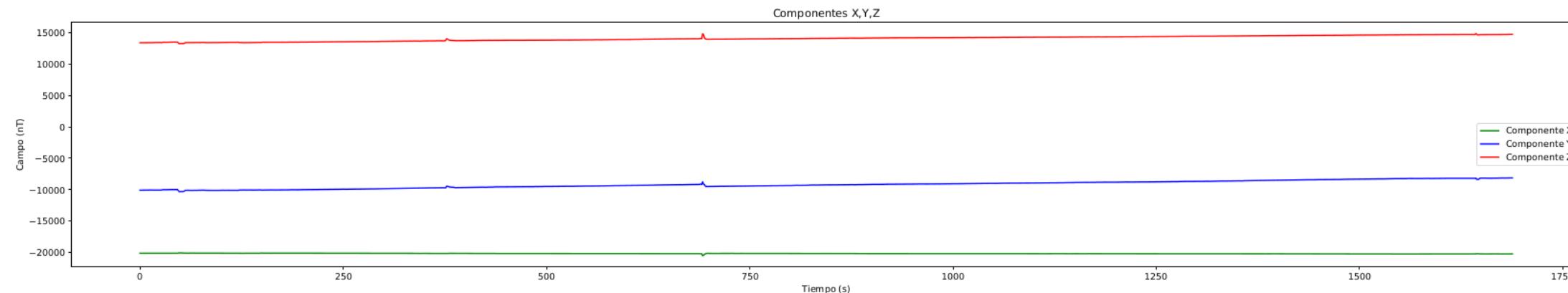
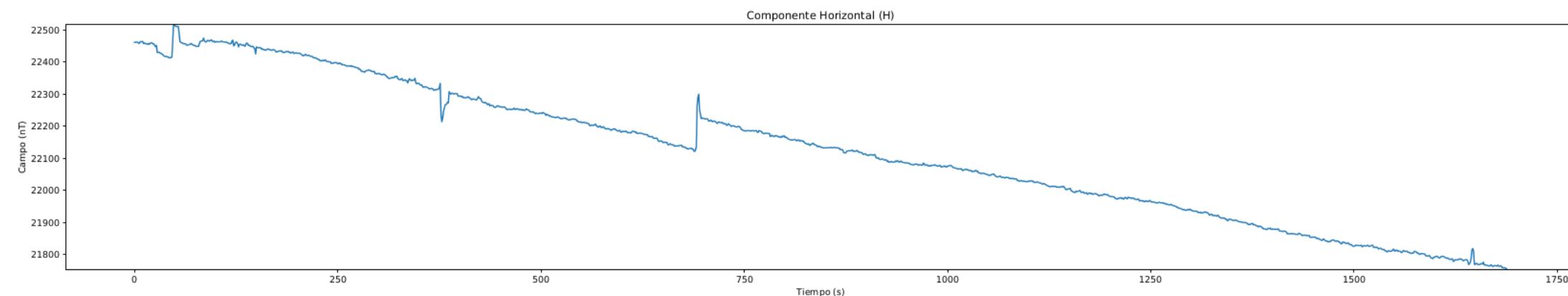
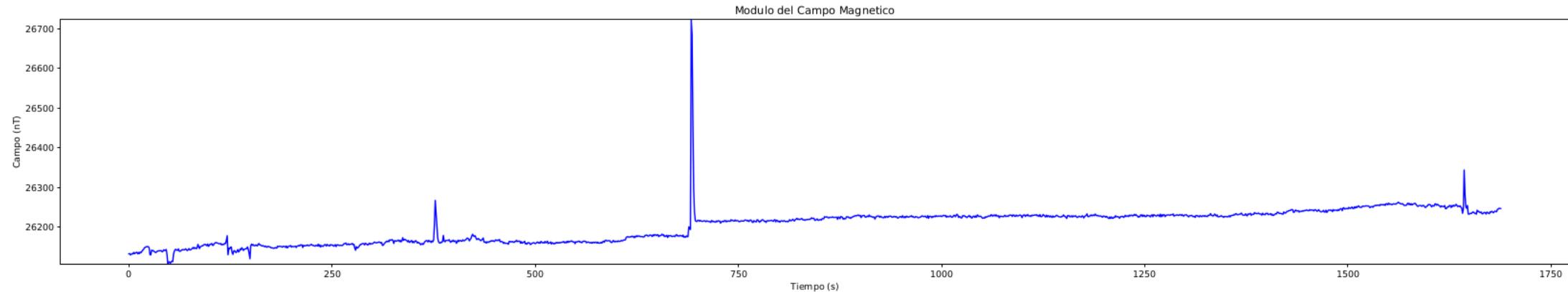


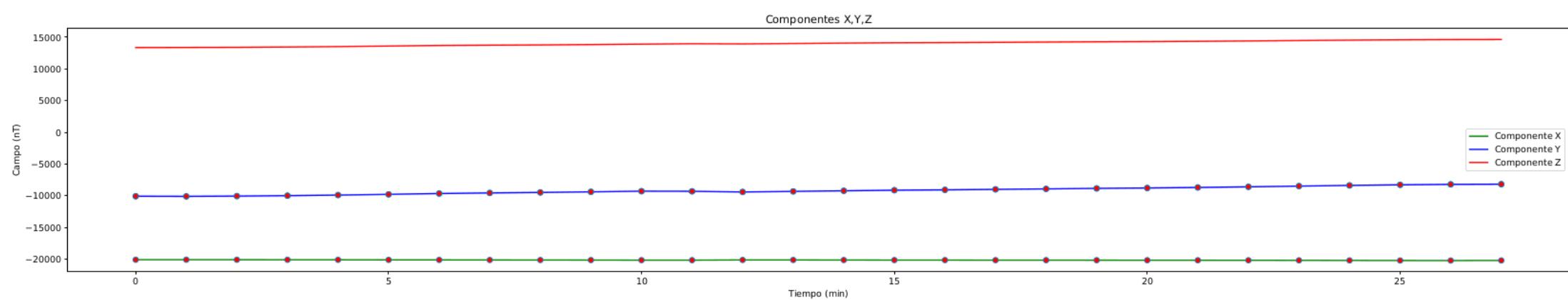
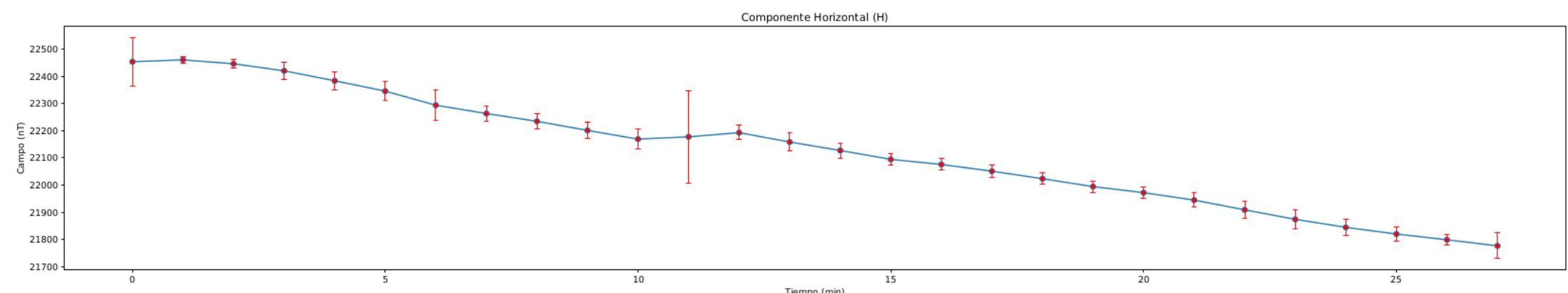
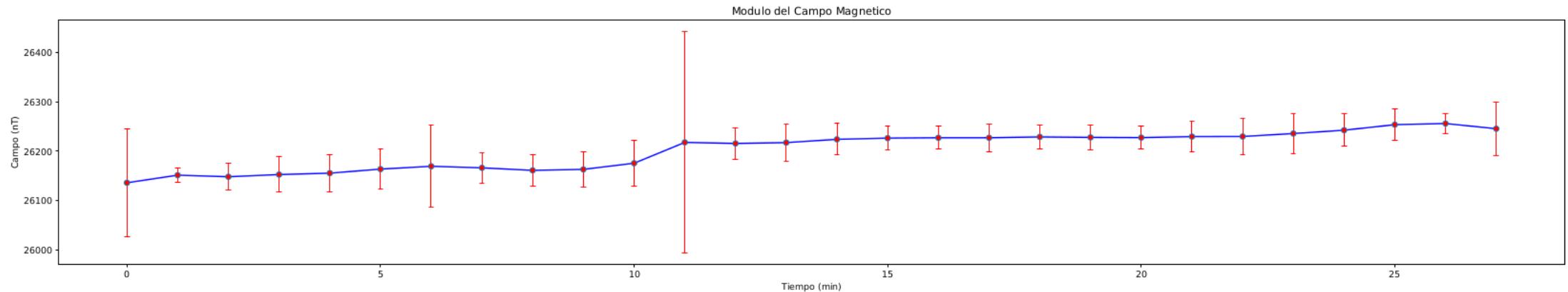
Con alimentación autónoma y medición de orientación



Prueba en campo, lejos de fuente de ruido





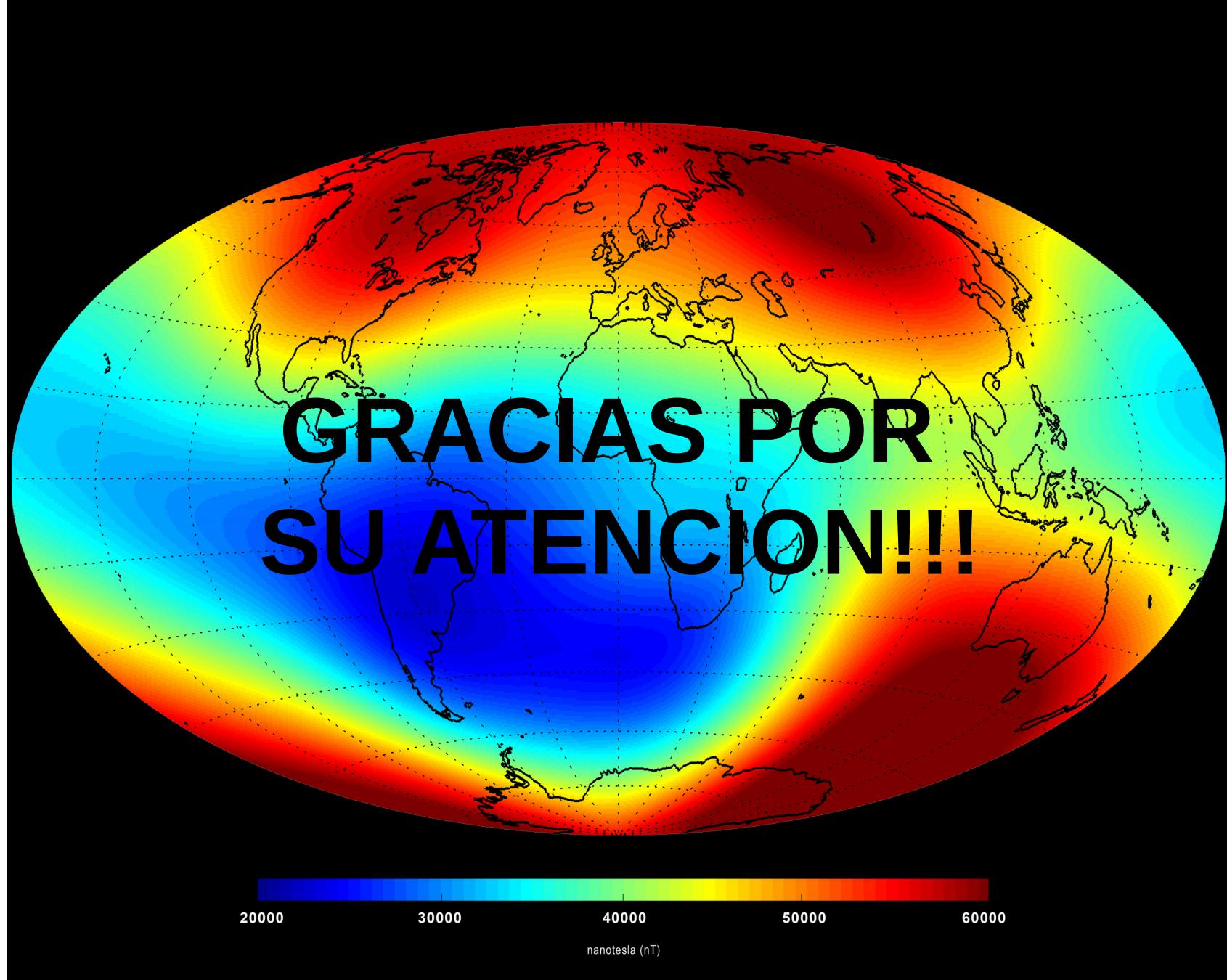


PREGUNTAS

COMO CALIBRAR SIN UNA CAJA BLINDADA O SALA BLINDADA????

TOMAR LAS CURVAS DE CALIBRACION EN CAMPO, ALEJADO DE FUENTES?

**SIN TENER MAGNETOMETROS DE REFERENCIA, HAY ESPERANZA DE TENER DATOS UTILES
PARA ANALISIS A NIVEL ACADEMICO??**



A	B	C	D	E	F	G	H	I	J	K
Estacion geomagnética										
Item	Costo USD	Cantidad	Total	Fuente						
Magnetómetro	40	3	120	https://www.fgsensors.com/						
Microcontrolador con Módulo de transmisión	35	2	70	https://www.adafruit.com/product/3078						
Modulo almacenamiento datos	3	1	3	https://www.amazon.com/Storage-Memory-Shield-Module-Arduino/dp/B01IPCAP72						
Bateria LiPo	25	1	25	https://www.amazon.com/Battery-Packs-Lithium-Polymer-1200mAh/dp/B00J2QET64						
Celda solar 5 o 7 V	10	1	10							
	TOTAL		228	1276800 Gs						

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