Coil install error analysis with FE method

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2018/04/06

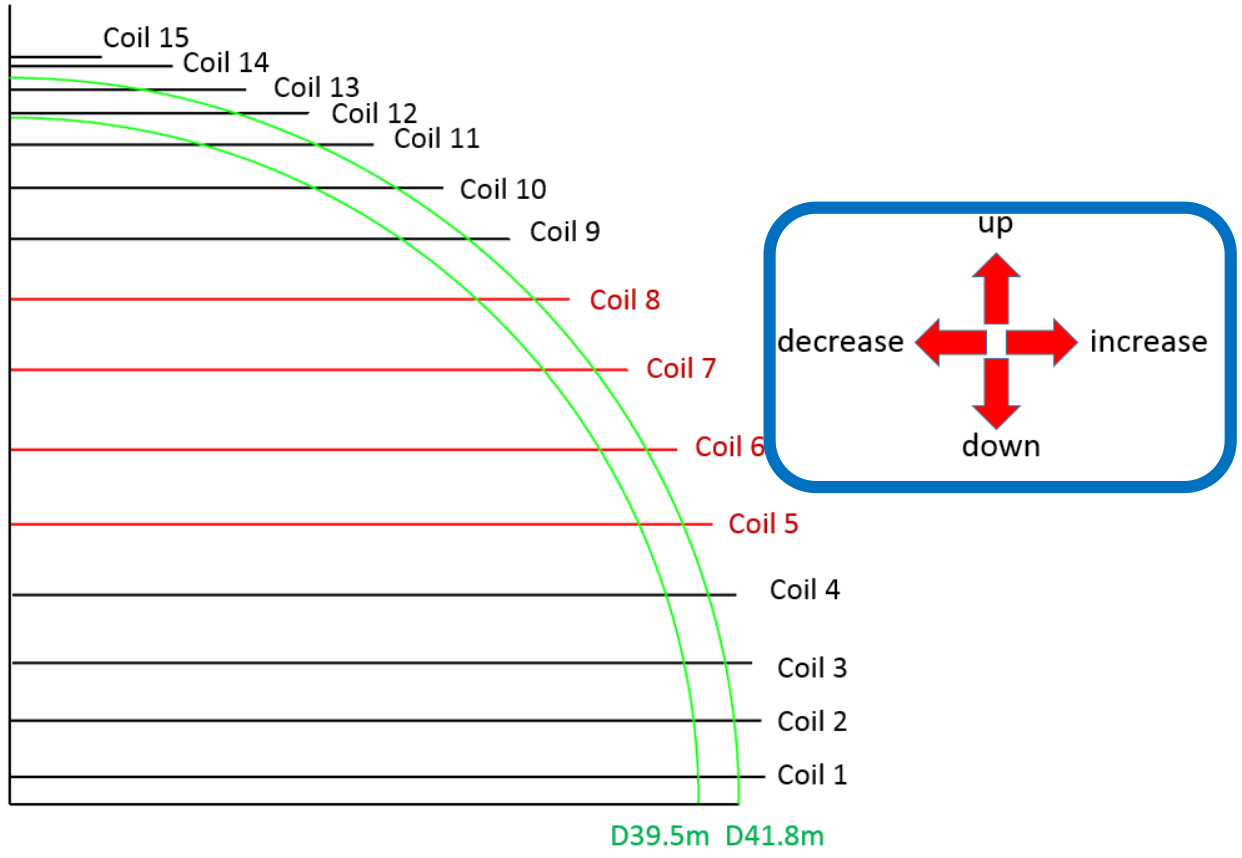
Outline

1. Install error analysis of 15 pairs of coil
2. Comparison of 15 pairs and 16 pairs plan
3. Summary

1. Install error analysis of 15 pairs of coil

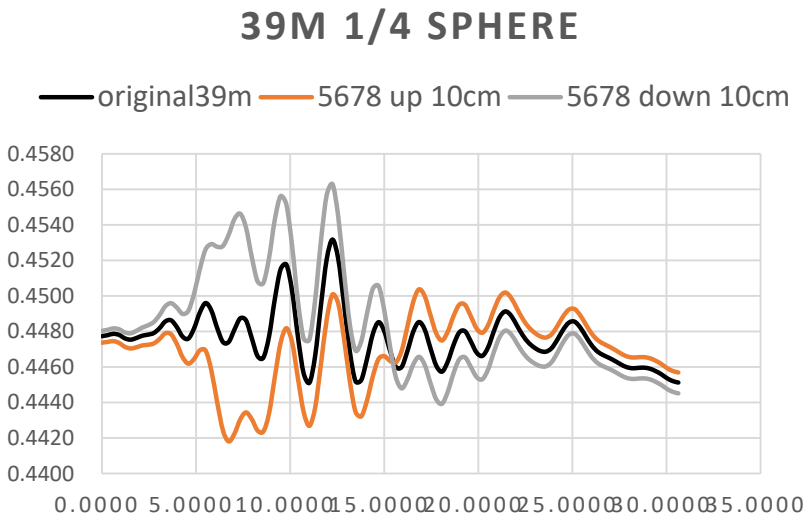
- This work is divided into two parts:
  1. Coils 5,6,7,8 move up 10 cm and down 10 cm along the axis ;
  2. The radius of coils 5,6,7,8 increase 20 cm and decrease 20 cm.

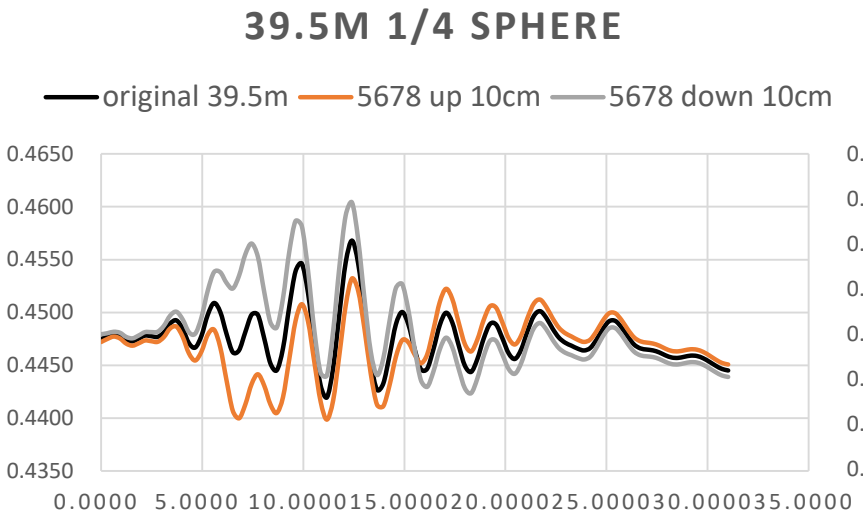
coil	Radial (m)	Axial(m)	Ampere(A)
1	21.64	0.79	89.677
2	21.52	2.38	89.677
3	21.26	4.06	102.488
4	20.8	6.01	115.299
5	20.1	8.05	115.299
6	19.1	10.2	128.11
7	17.69	12.49	128.11
8	16.02	14.56	102.488
9	14.3	16.26	89.677
10	12.4	17.75	76.866
11	10.39	19	64.055
12	8.53	19.9	38.433
13	6.74	20.56	38.433
14	4.62	21.26	25.622
15	2.59	21.5	12.811

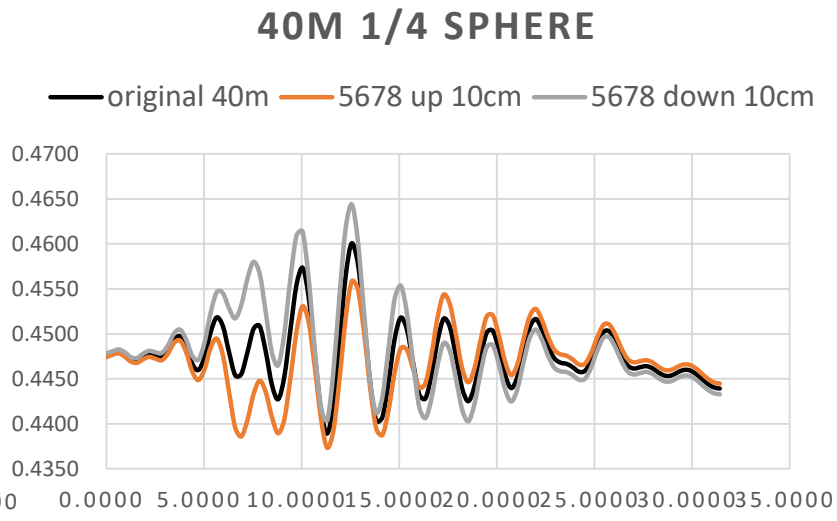


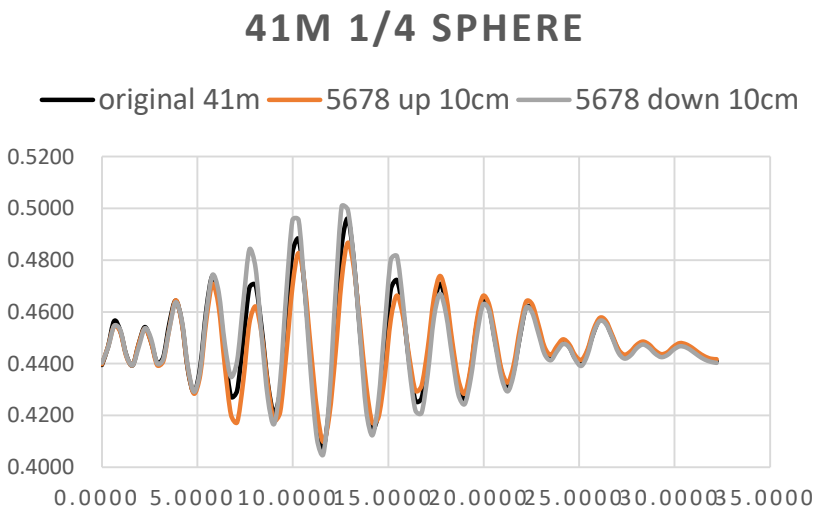
Magnetic field distribution

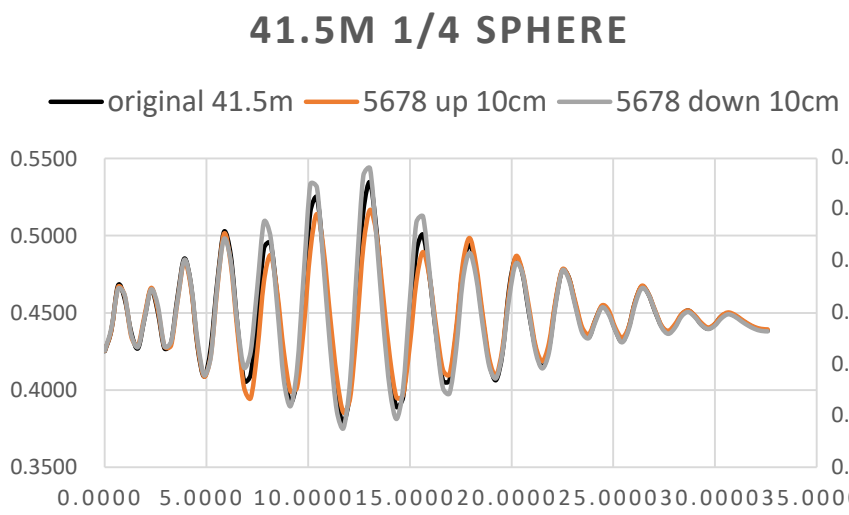
1, Coils 5,6,7,8 move up 10 cm and down 10 cm along the axis. The magnetic field of ¼ circle.

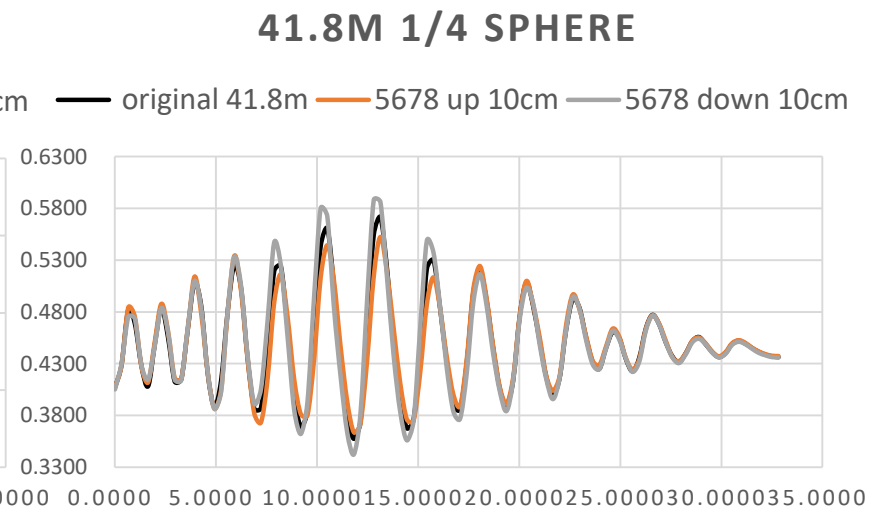












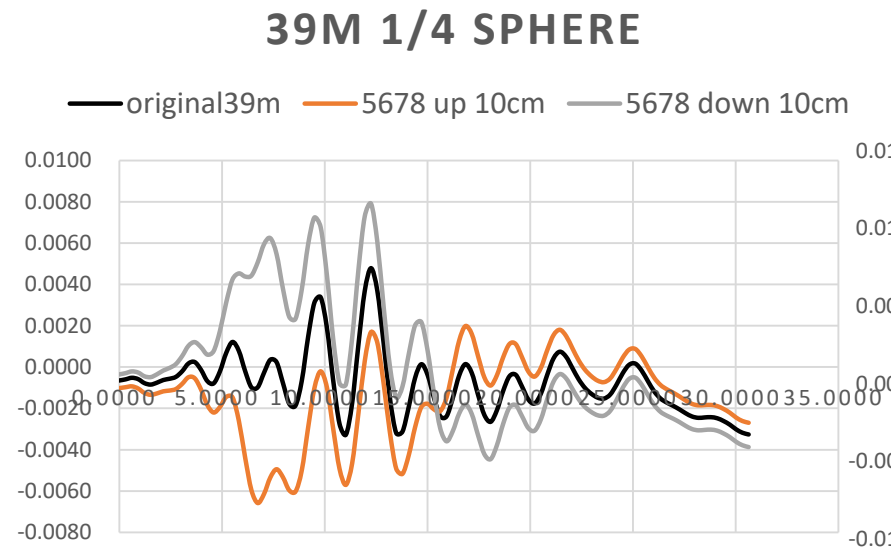
The generated field deviation comparisons

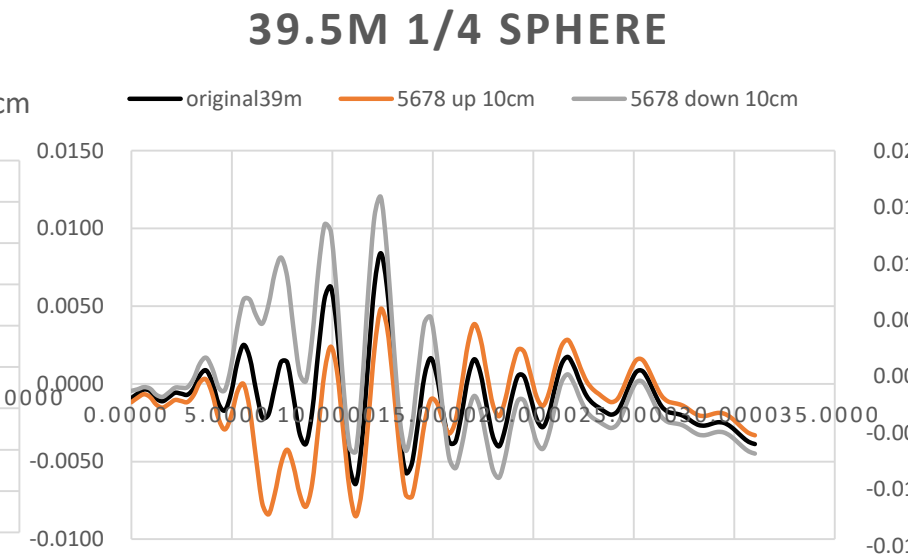
$$Max - to - EMF\ Deviation = \frac{|\ Max\ or\ Min\ | - EMF}{EMF} \times 100\%$$

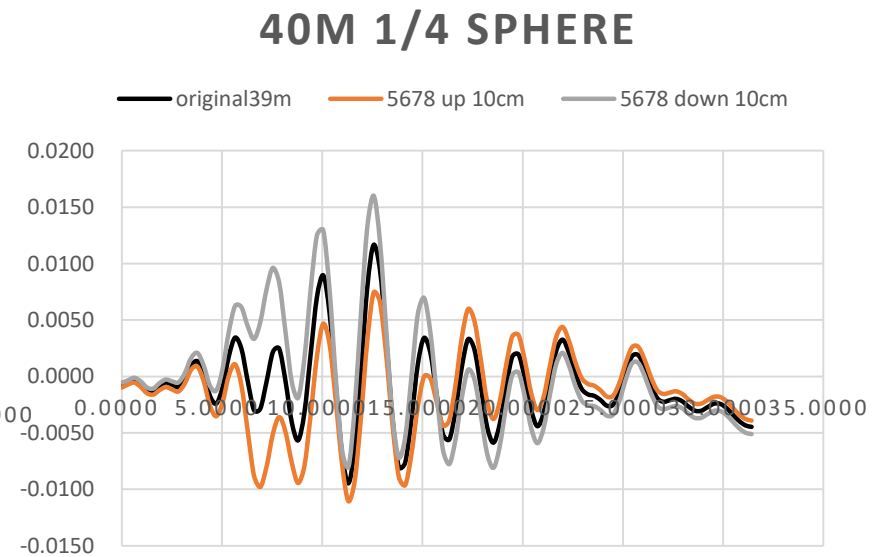
Diameter (m)	Original			5,6,7,8 up 10 cm			5,6,7,8 down 10 cm		
	Maximum field strength (Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)	Maximum field strength(Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)	Maximum field strength(Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)
39	0.4532	0.4451	**1.07**	0.4504	0.4418	1.47	0.4563	0.4439	1.76
39.5	0.4568	0.4420	**1.88**	0.4532	0.4399	1.89	0.4604	0.4424	2.68
40	0.4601	0.4389	2.61	0.4558	0.4373	**2.47**	0.4644	0.4403	3.57
41	0.4960	0.4075	10.62	0.4867	0.4097	**8.63**	0.5007	0.4049	11.67
41.5	0.5346	0.3790	19.23	0.5167	0.3854	**15.23**	0.5437	0.3752	21.26
41.8	0.5717	0.3573	27.5	0.5524	0.3636	**23.2**	0.5882	0.3422	31.18

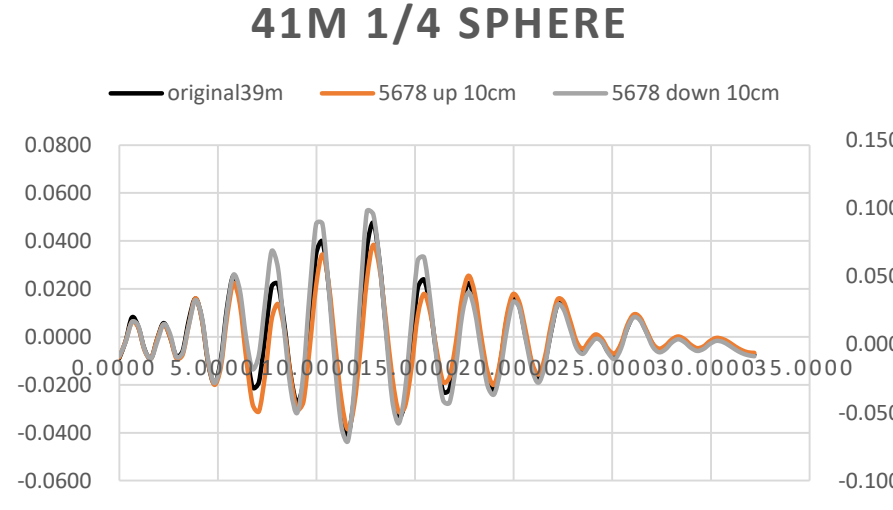
Residual magnetic field distribution

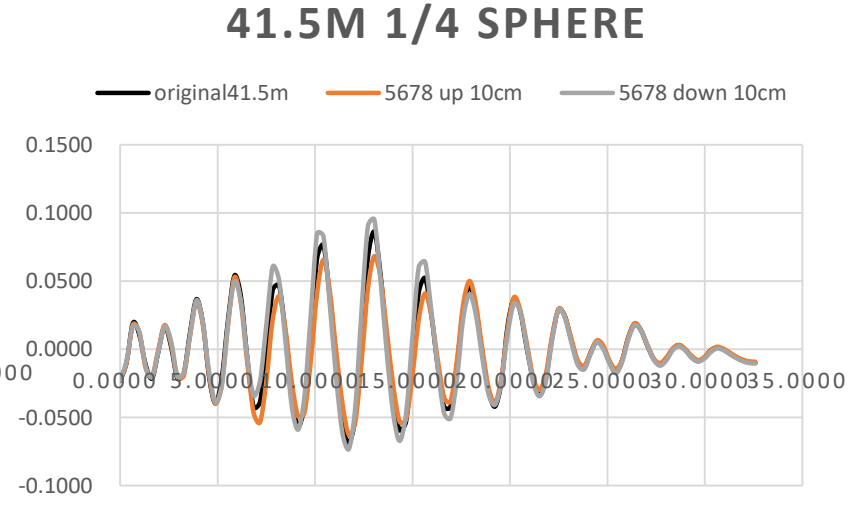
1, Coils 5,6,7,8 move up 10 cm and down 10 cm along the axis. The magnetic field of ¼ circle.

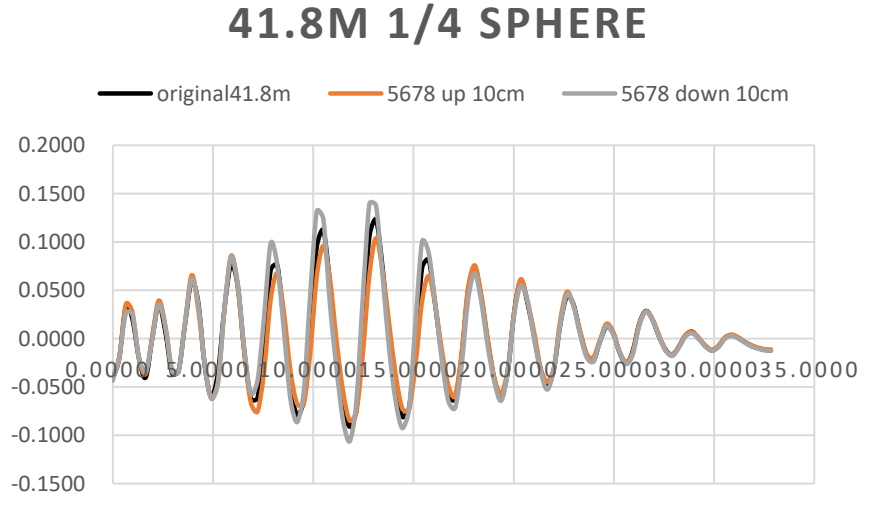












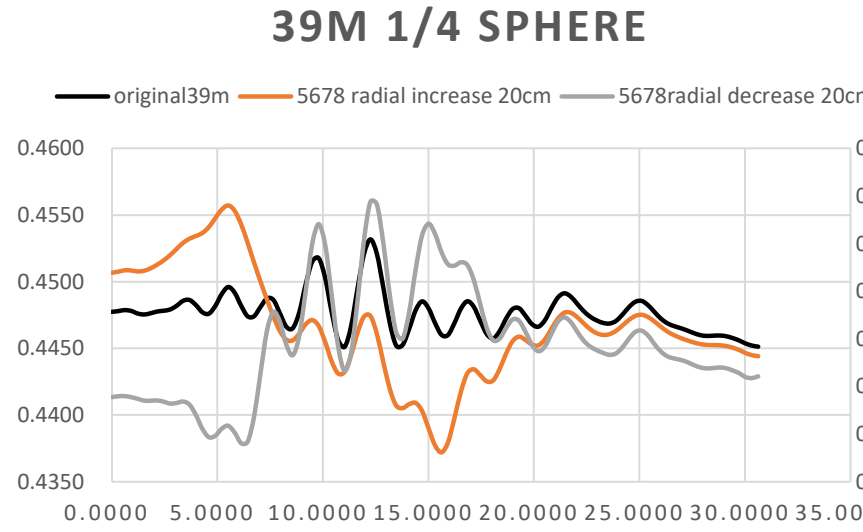
The residual magnetic field comparison

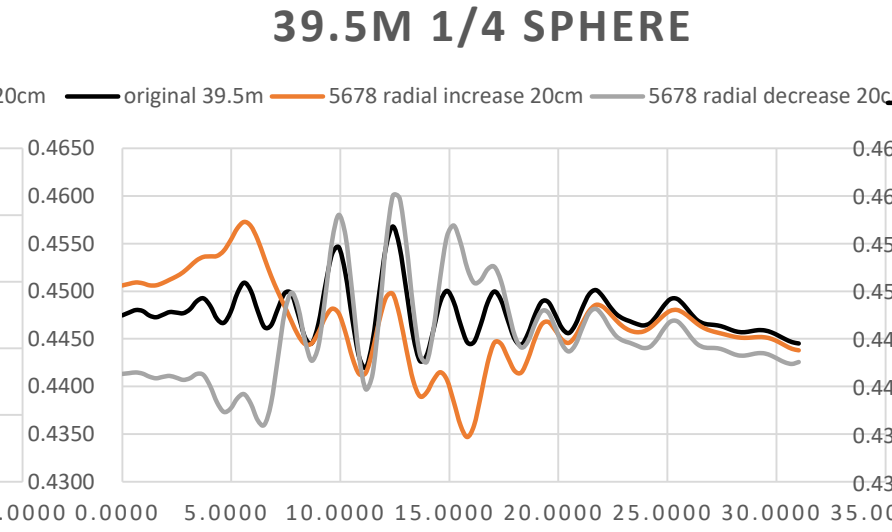
$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

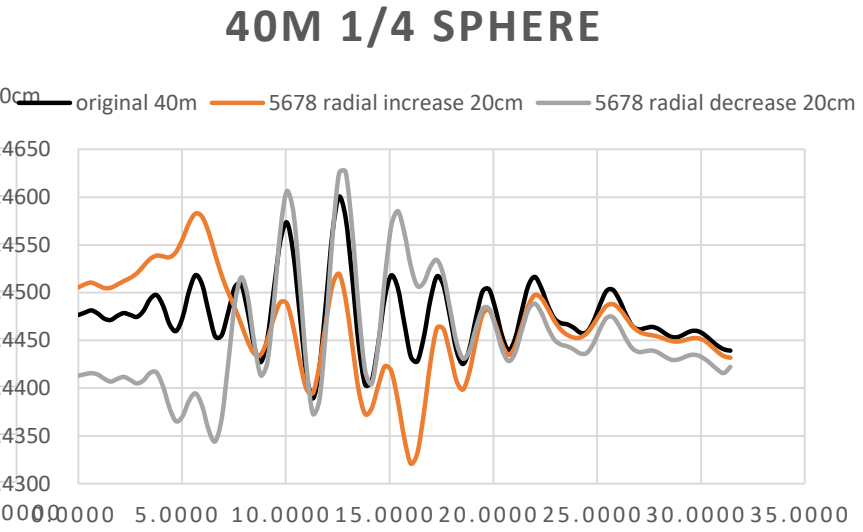
Diameter (m)	Original		5,6,7,8 up 10 cm		5,6,7,8 down 10 cm	
	Absolute Max residual field (Gs)	Deviation (%)	Absolute Max residual field (Gs)	Deviation (%)	Absolute Max residual field (Gs)	Deviation (%)
39	0.0048	**1.07**	0.0066	1.47	0.0066	1.47
39.5	0.0084	**1.87**	0.0085	1.90	0.012	2.68
40	0.0117	2.61	0.0111	**2.48**	0.016	3.57
41	0.0476	10.62	0.0386	**8.61**	0.0523	11.66
41.5	0.0862	19.22	0.0683	**15.23**	0.0953	21.25
41.8	0.1233	27.50	0.104	**23.19**	0.1398	31.18

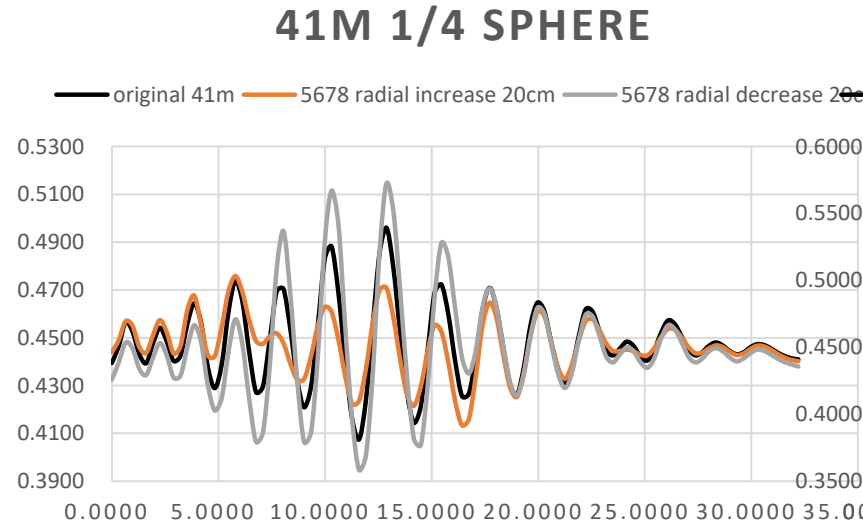
Magnetic field distribution

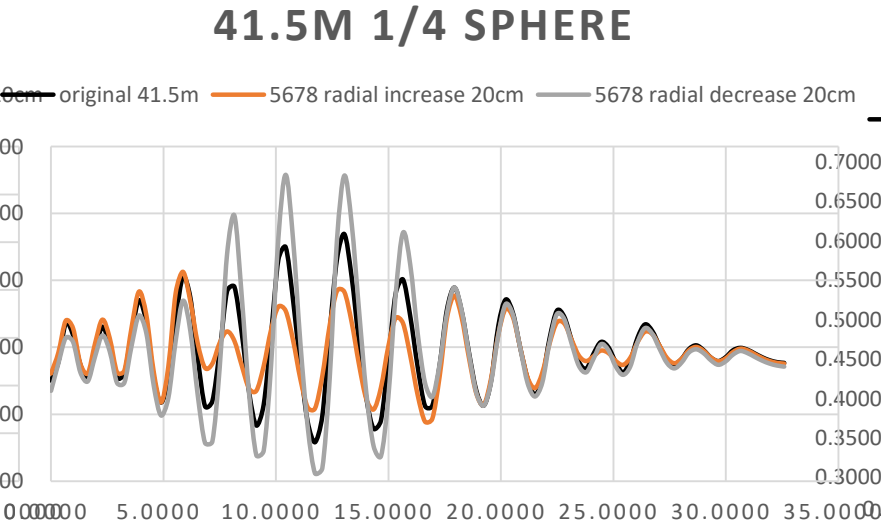
2, The radius of coils 5,6,7,8 increase 20 cm and decrease 20 cm. The magnetic field of ¼ circle.

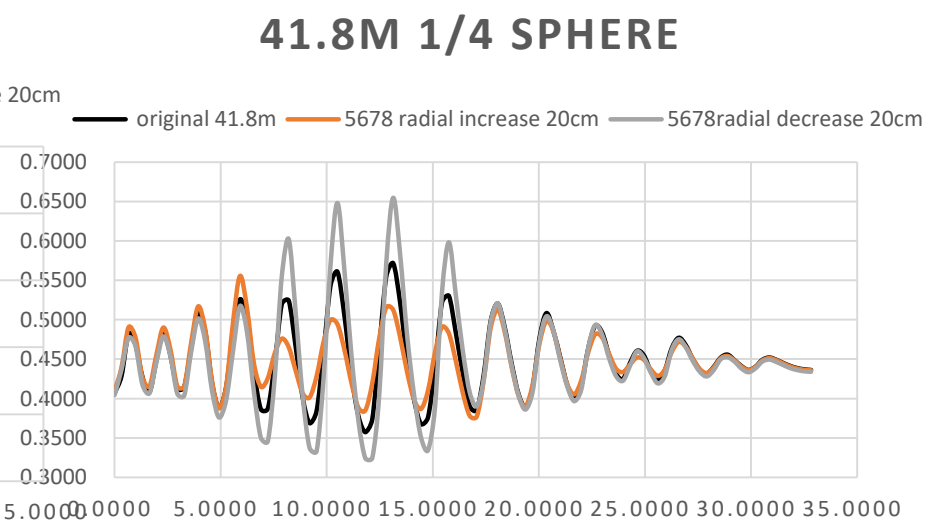












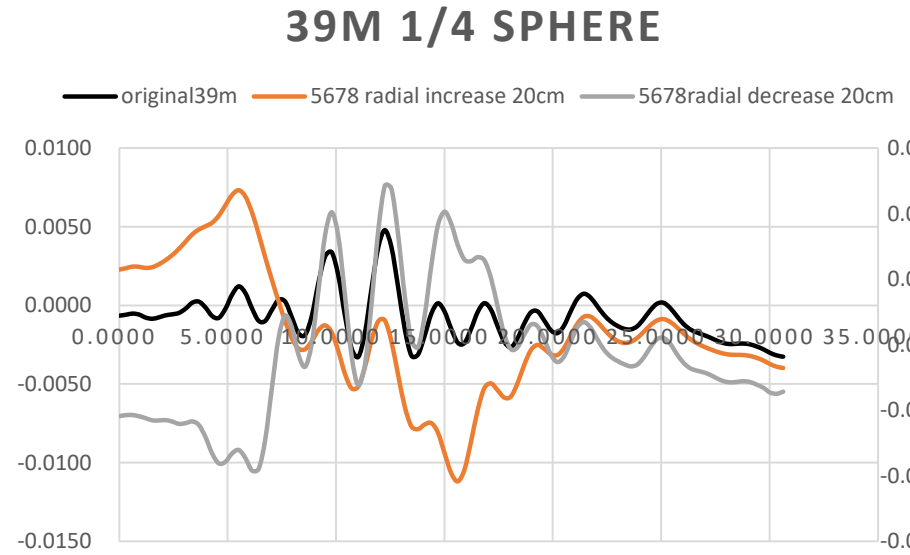
The generated field deviation comparisons

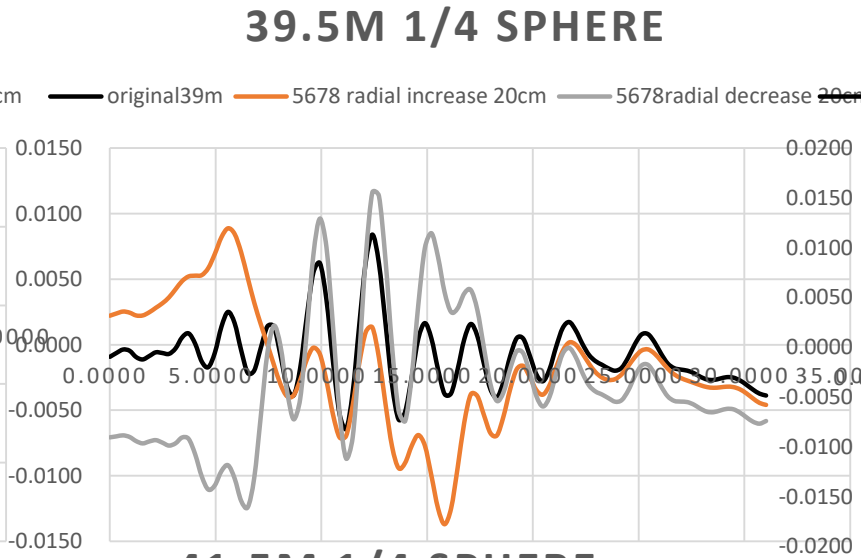
$$Max - to - EMF\ Deviation = \frac{|\ Max\ or\ Min\ | - EMF}{EMF} \times 100\%$$

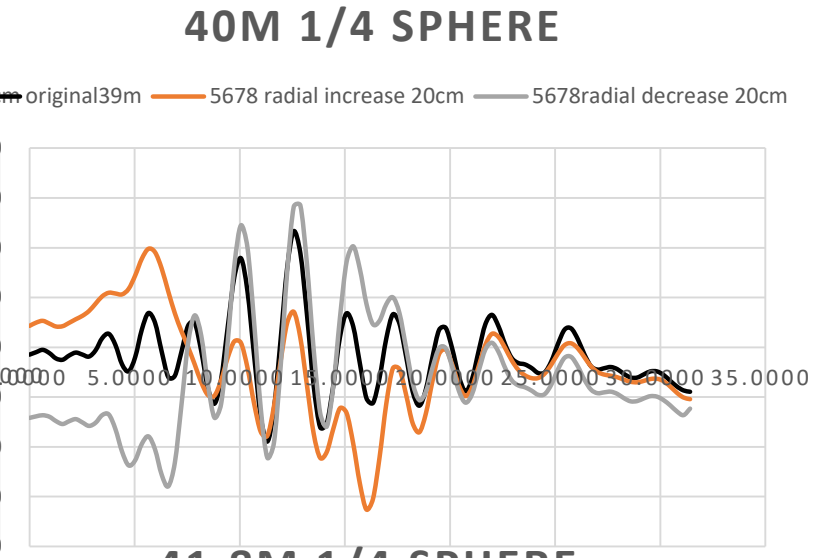
Diameter (m)	Original			5,6,7,8 increase 20 cm			5,6,7,8 decrease 20 cm		
	Maximum field strength (Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)	Maximum field strength(Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)	Maximum field strength(Gs)	Minimum field strength(Gs)	Max-to-EMF deviation (%)
39	0.4532	0.4451	**1.07**	0.4557	0.4372	2.50	0.4558	0.438	2.34
39.5	0.4568	0.4420	**1.88**	0.4568	0.4347	3.06	0.4597	0.4360	2.77
40	0.4601	0.4389	**2.61**	0.4579	0.4321	3.64	0.4626	0.4344	3.19
41	0.4960	0.4075	10.62	0.4758	0.4133	**7.83**	0.5146	0.3947	14.76
41.5	0.5346	0.3790	19.23	0.5064	0.3945	**12.94**	0.5789	0.3558	29.10
41.8	0.5717	0.3573	27.5	0.5555	0.3772	**23.89**	0.6546	0.3246	46.01

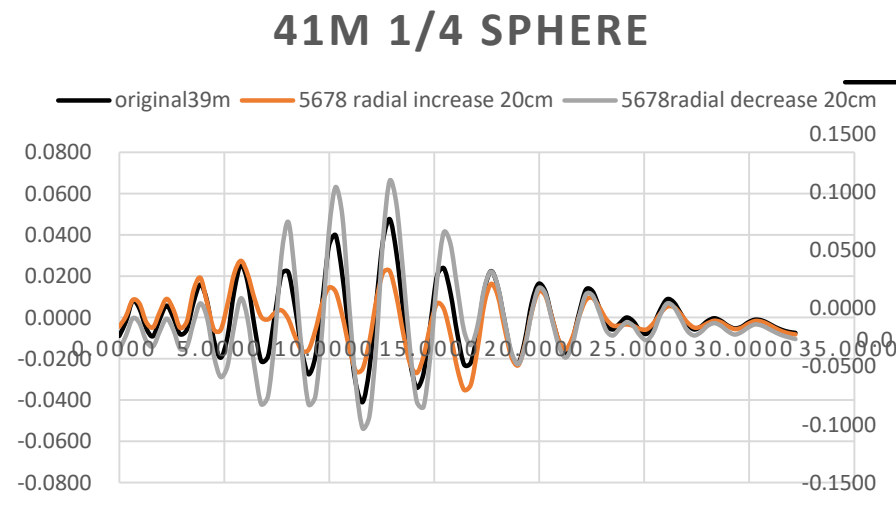
Residual magnetic field distribution

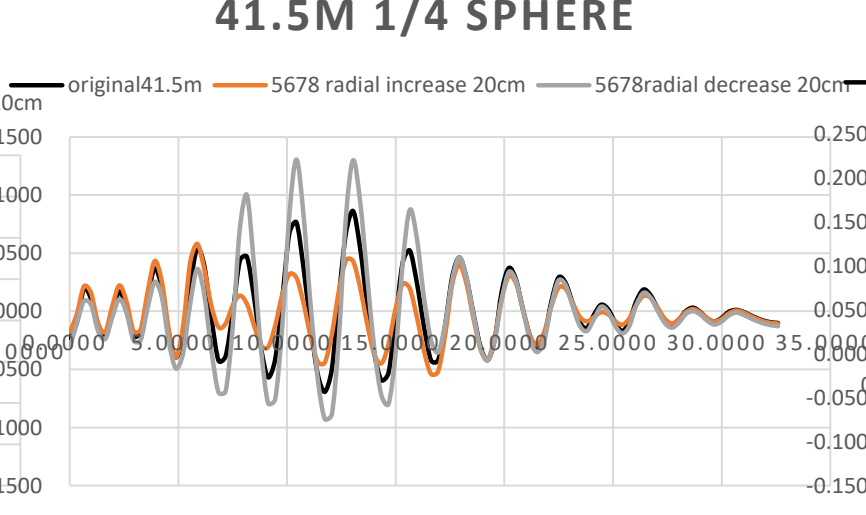
2, The radius of coils 5,6,7,8 increase 20 cm and decrease 20 cm. The magnetic field of ¼ circle.

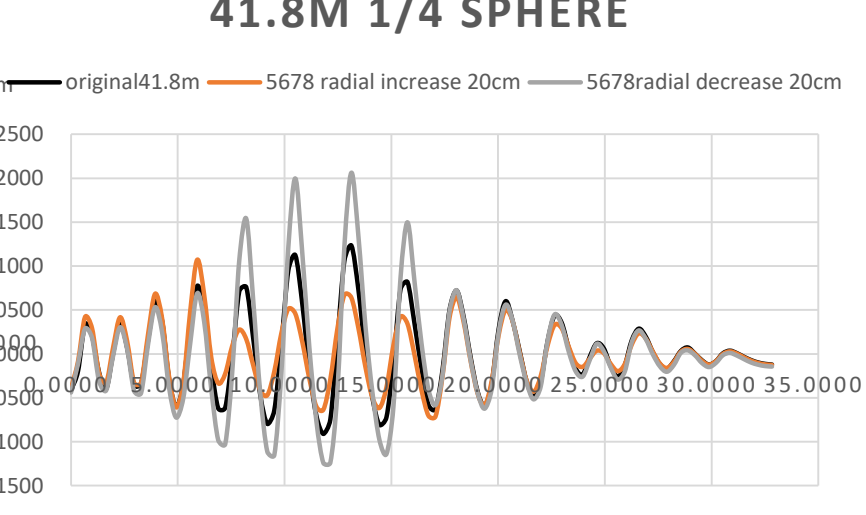












The residual magnetic field comparison

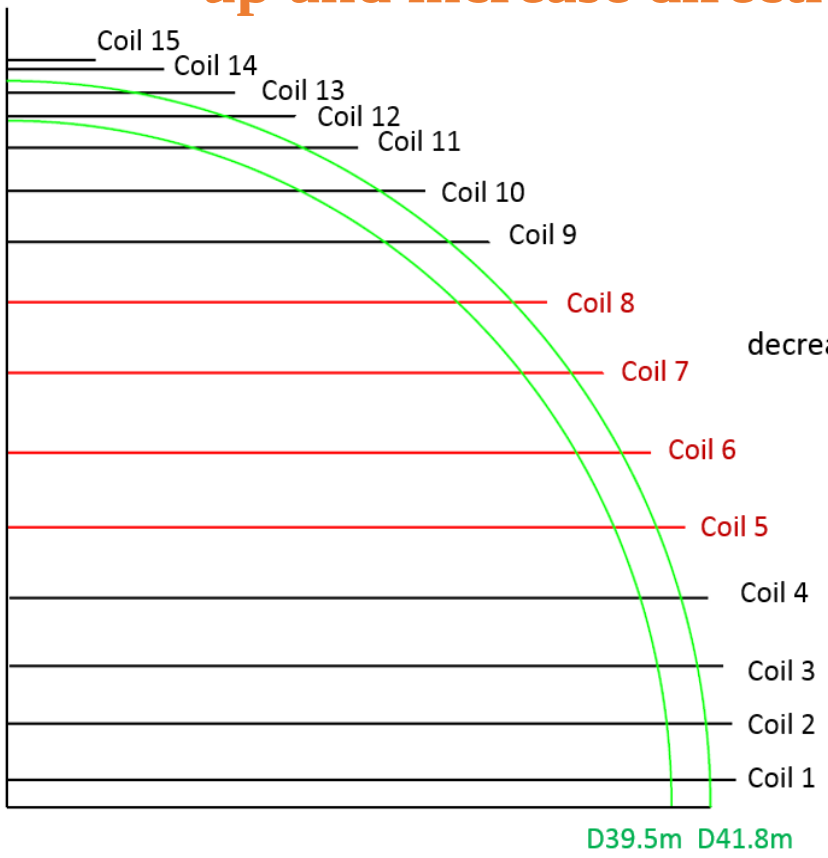
$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

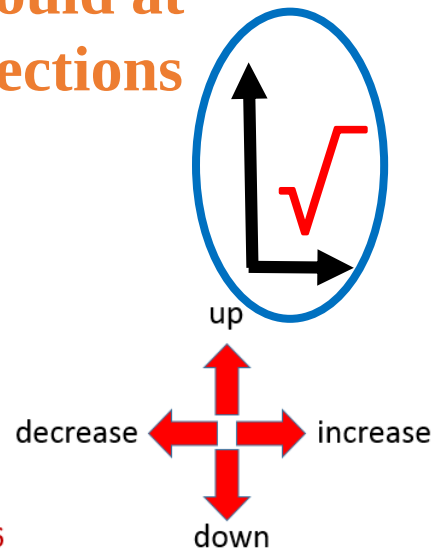
Diameter (m)	Original		5,6,7,8 increase 20 cm		5,6,7,8 decrease 20 cm	
	Absolute Max residual field (Gs)	Deviation (%)	Absolute Max residual field (Gs)	Deviation (%)	Absolute Max residual field (Gs)	Deviation (%)
39	0.0048	**1.07**	0.0112	2.50	0.0105	2.34
39.5	0.0084	**1.87**	0.0137	3.06	0.0124	2.77
40	0.0117	**2.61**	0.0163	3.64	0.0143	3.19
41	0.0476	10.62	0.0351	**7.83**	0.0662	14.76
41.5	0.0862	19.22	0.0580	**12.94**	0.1305	29.10
41.8	0.1233	27.50	0.1071	**23.89**	0.2063	46.01

Coil install error analysis

Diameter (m)	Max-to-EMF deviation (%)				
	Original	**5,6,7,8 up 10 cm**	**5,6,7,8 down 10 cm**	**5,6,7,8 increase 20 cm**	**5,6,7,8 decrease 20 cm**
39	**1.07**	1.47	1.76	**2.50**	2.34
39.5	**1.88**	1.89	2.68	**3.06**	2.77
40	2.61	**2.47**	3.57	**3.64**	3.19
41	10.62	8.63	11.67	**7.83**	**14.76**
41.5	19.23	15.23	21.26	**12.94**	**29.10**
41.8	27.5	**23.2**	31.18	23.89	**46.01**

The install error should at up and increase directions





2. Comparison of 15 pairs and 16 pairs plan

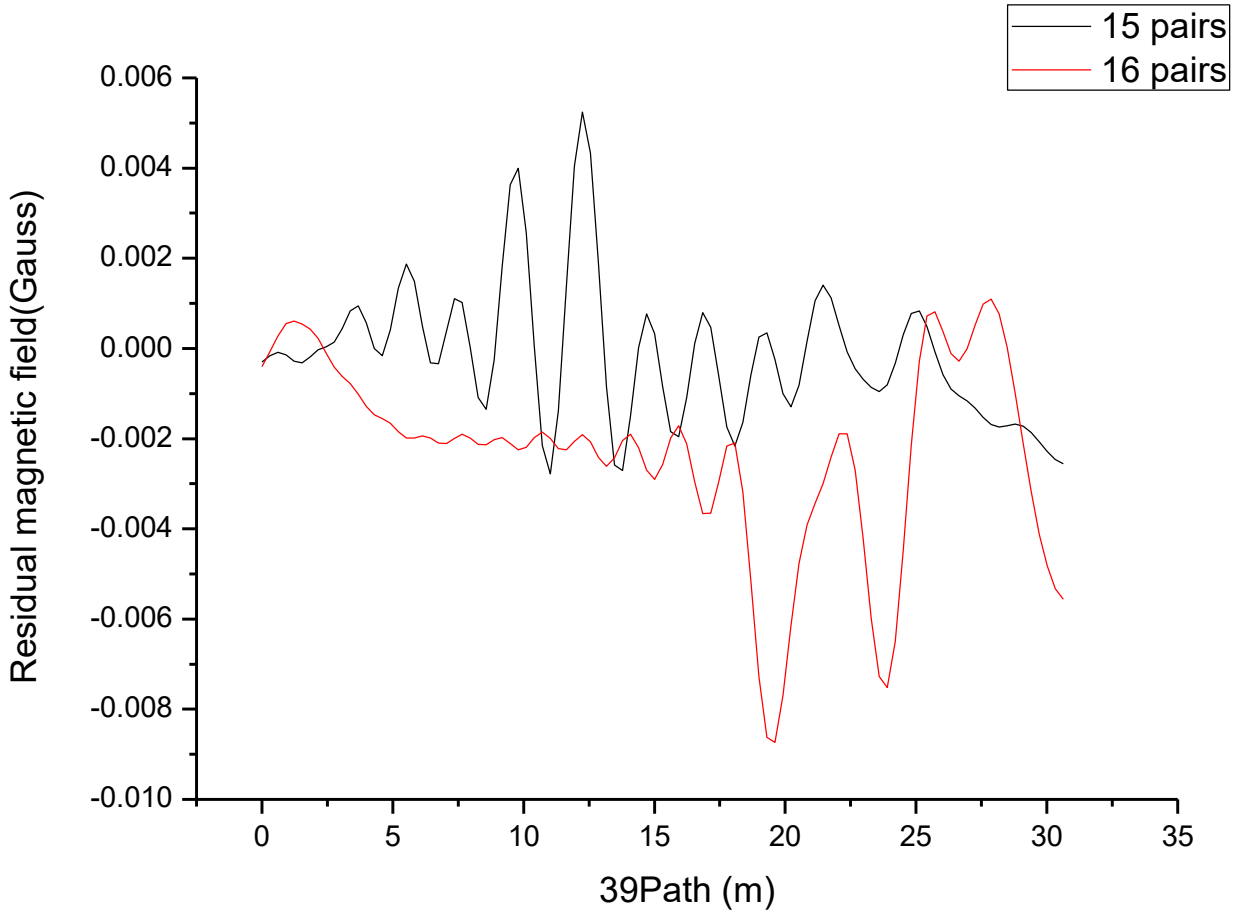
15 pairs of coils

coil	Radial (m)	Axial(m)	Ampere(A)
1	21.64	0.79	85.54
2	21.52	2.38	85.54
3	21.26	4.06	97.76
4	20.8	6.01	109.98
5	20.1	8.05	109.98
6	19.1	10.2	122.2
7	17.69	12.49	122.2
8	16.02	14.56	97.76
9	14.3	16.26	85.54
10	12.4	17.75	73.32
11	10.39	19	61.1
12	8.53	19.9	36.66
13	6.74	20.56	36.66
14	4.62	21.26	24.44
15	2.59	21.5	12.22

16 pairs of coils

COIL	R(m)	H(m)	I(A)
1	3.90	21.30	26.362
2	6.57	20.63	52.72
3	9.25	19.58	52.72
4	11.12	18.58	65.9
5	13.28	17.10	79.08
6	14.996	15.62	79.08
7	16.399	14.14	79.08
8	17.57	12.66	79.08
9	18.54	11.18	79.08
10	19.36	9.70	79.08
11	20.03	8.22	79.08
12	20.58	6.74	79.08
13	21.01	5.26	79.08
14	21.32	3.78	79.08
15	21.53	2.30	79.08
16	21.639	0.82	85.67

39m ¼ sphere surface



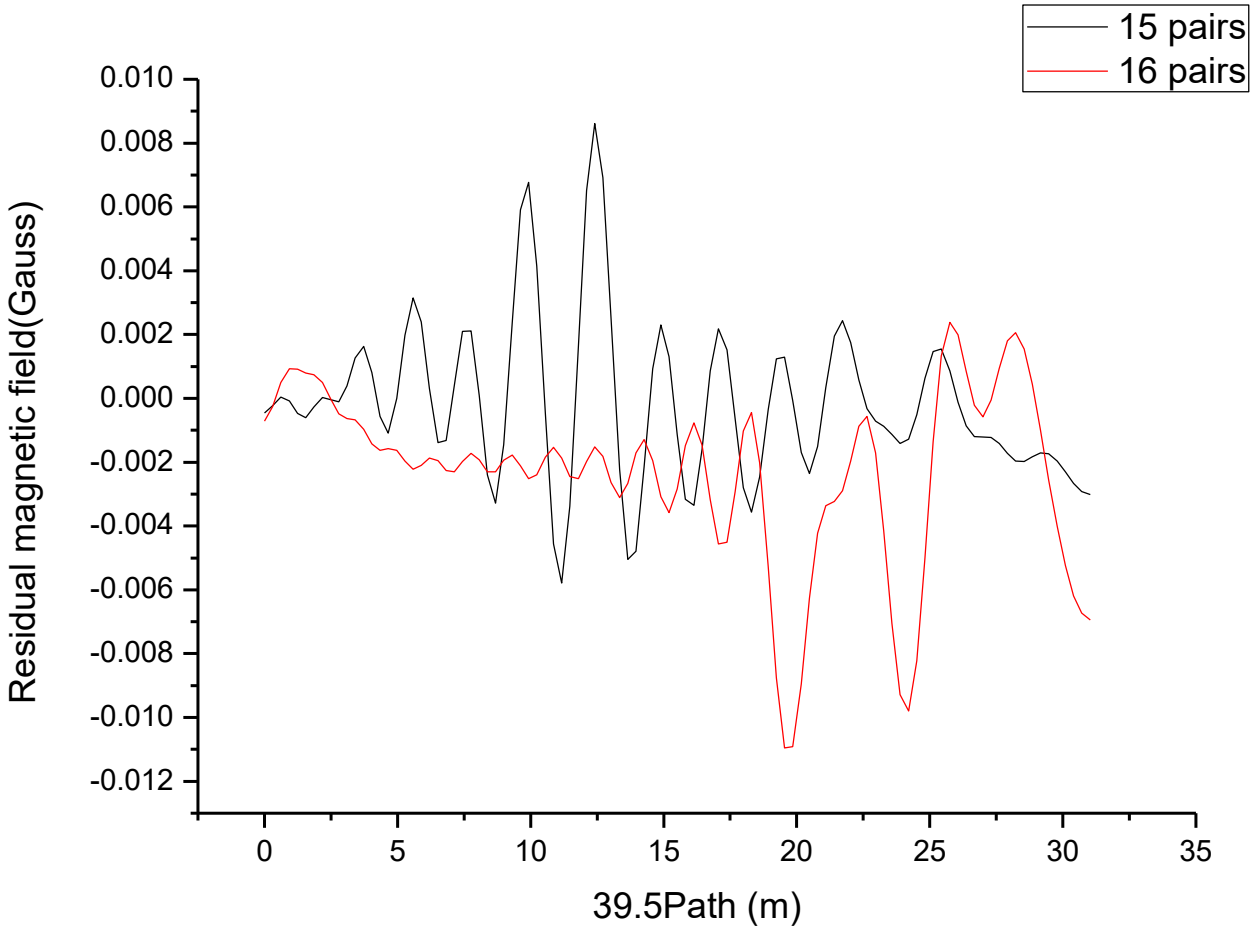
Residual magnetic field distribution

$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

EMF=0.44839 Gauss

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.0052	1.16
16 pairs	0.0087	1.94

39.5m ¼ sphere surface



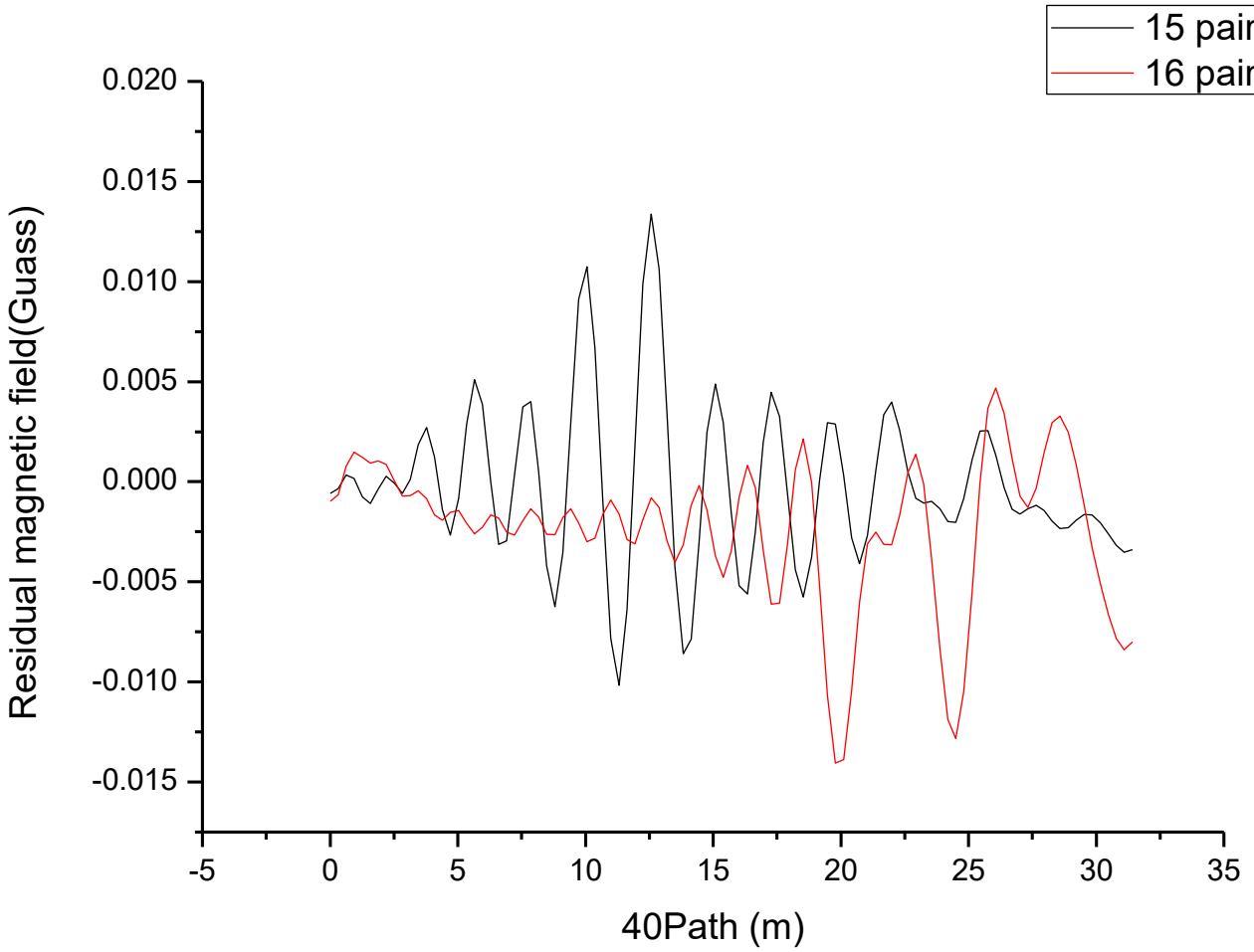
Residual magnetic field distribution

$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

EMF=0.44839 Gauss

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.0086	1.9
16 pairs	0.011	2.45

40m ¼ sphere surface



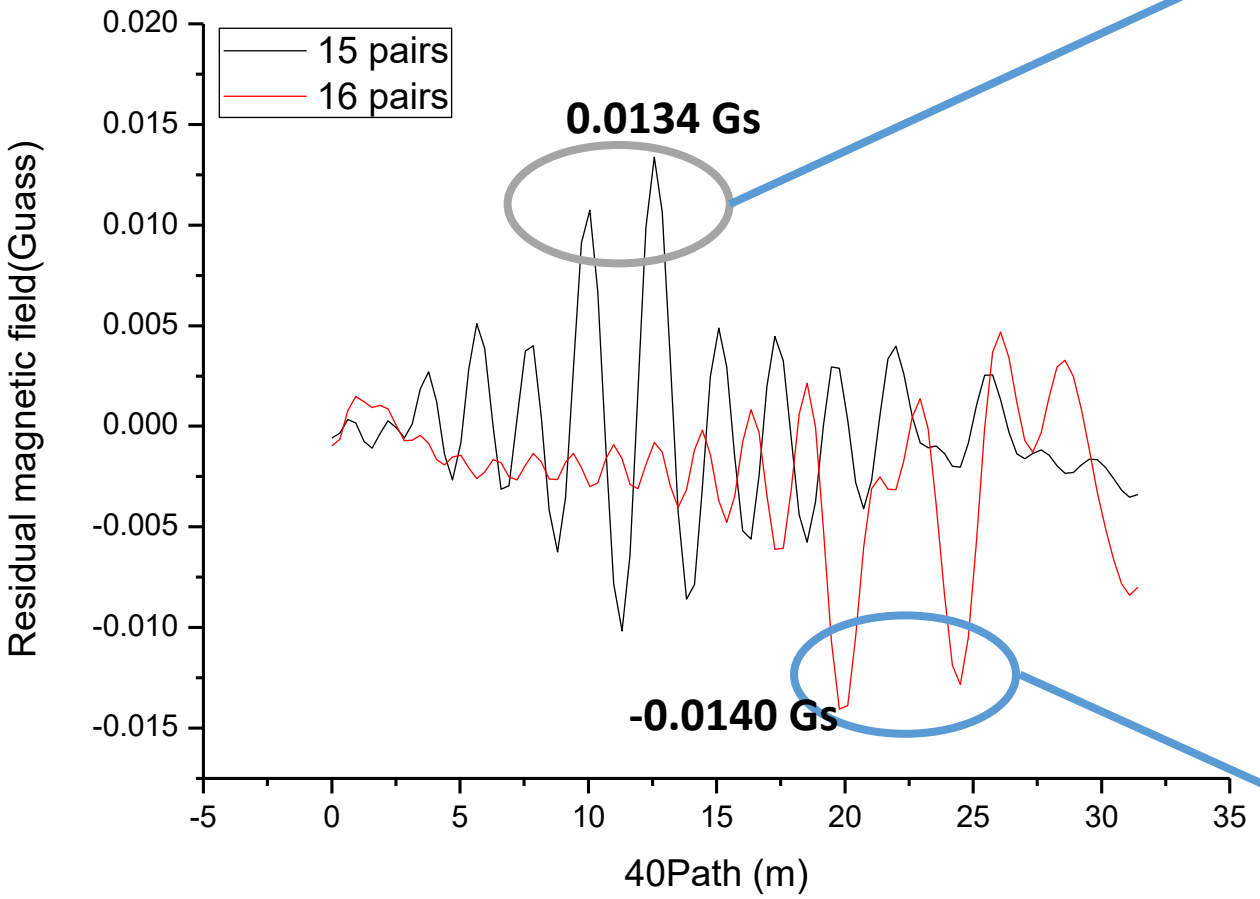
Residual magnetic field distribution

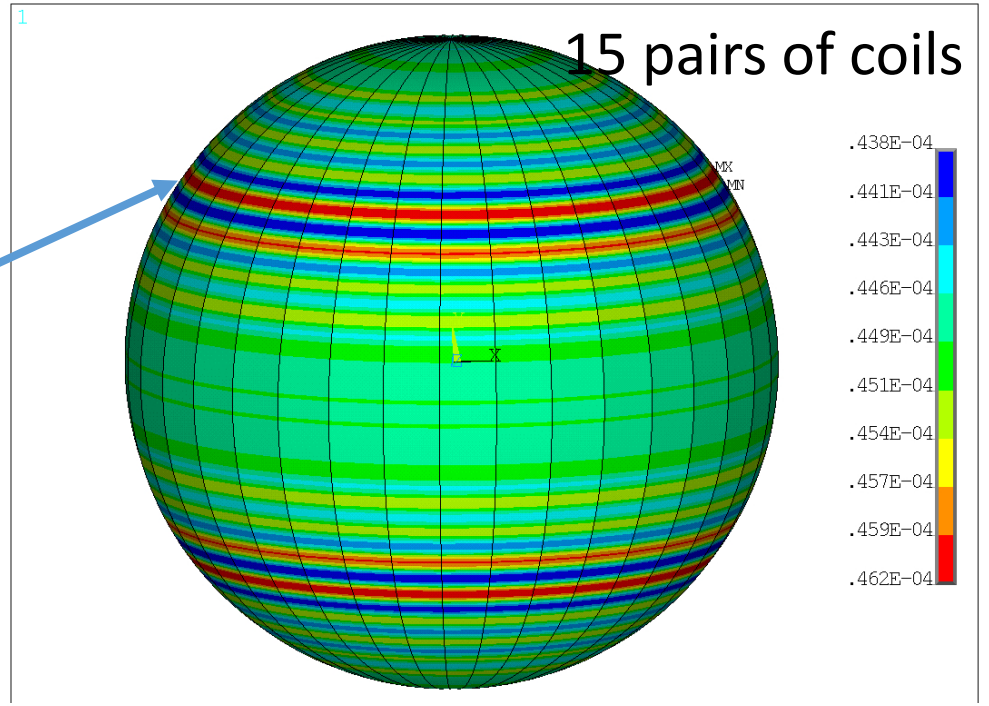
$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

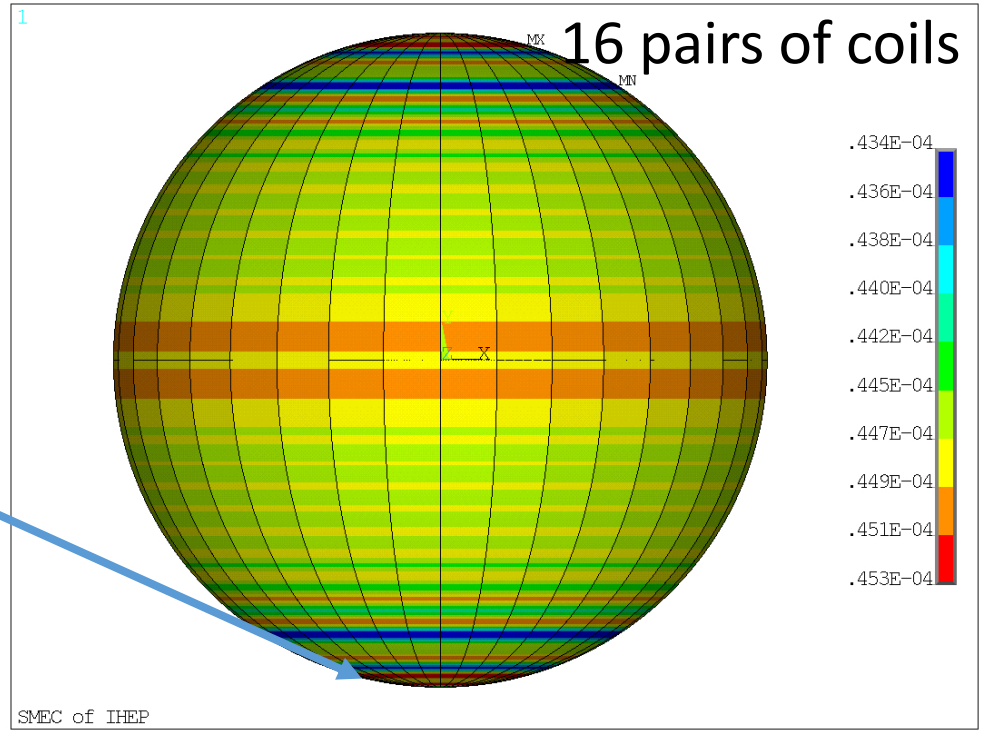
EMF=0.44839 Gauss

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.0134	2.99
16 pairs	0.0140	3.12

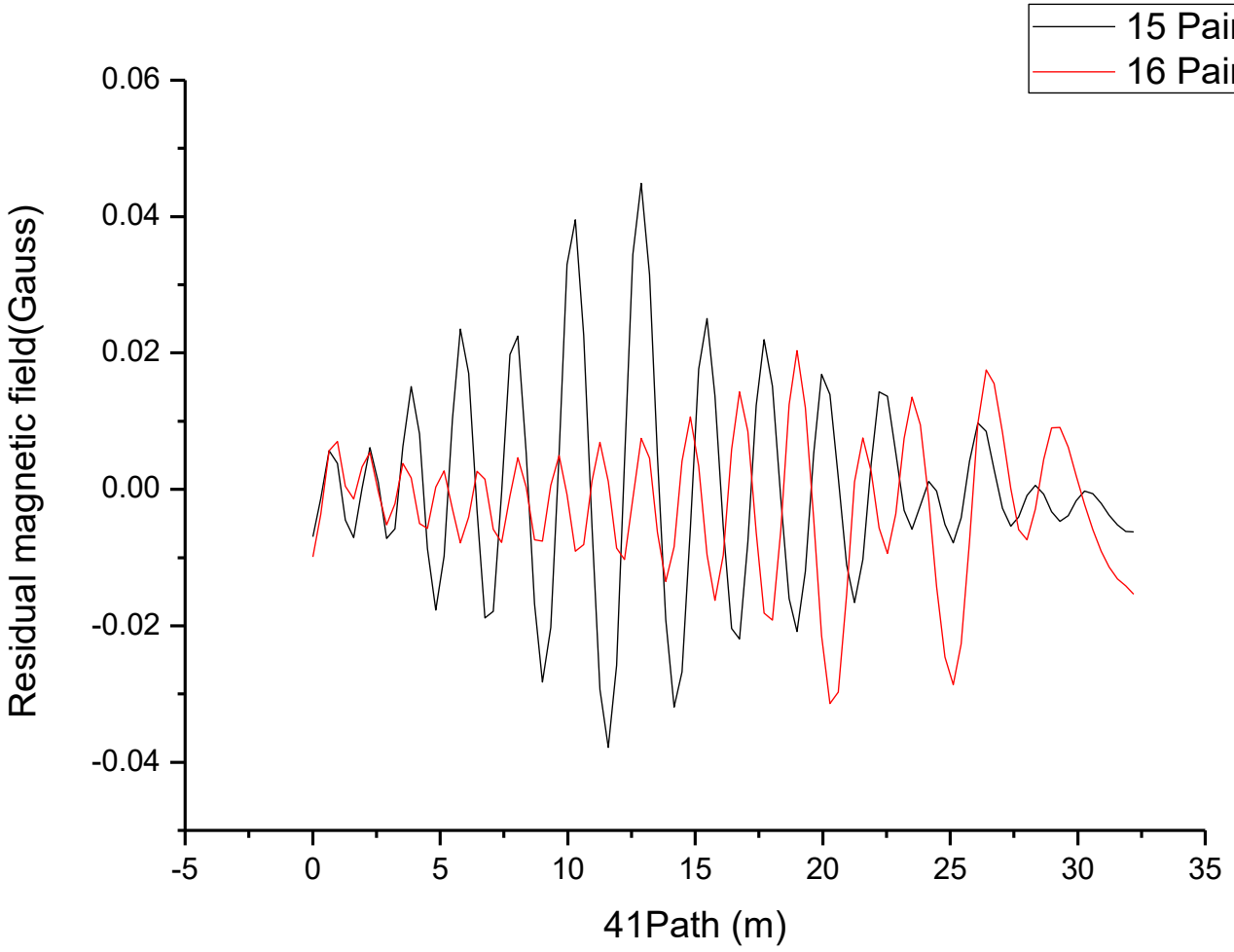
40m sphere surface







41m ¼ sphere surface



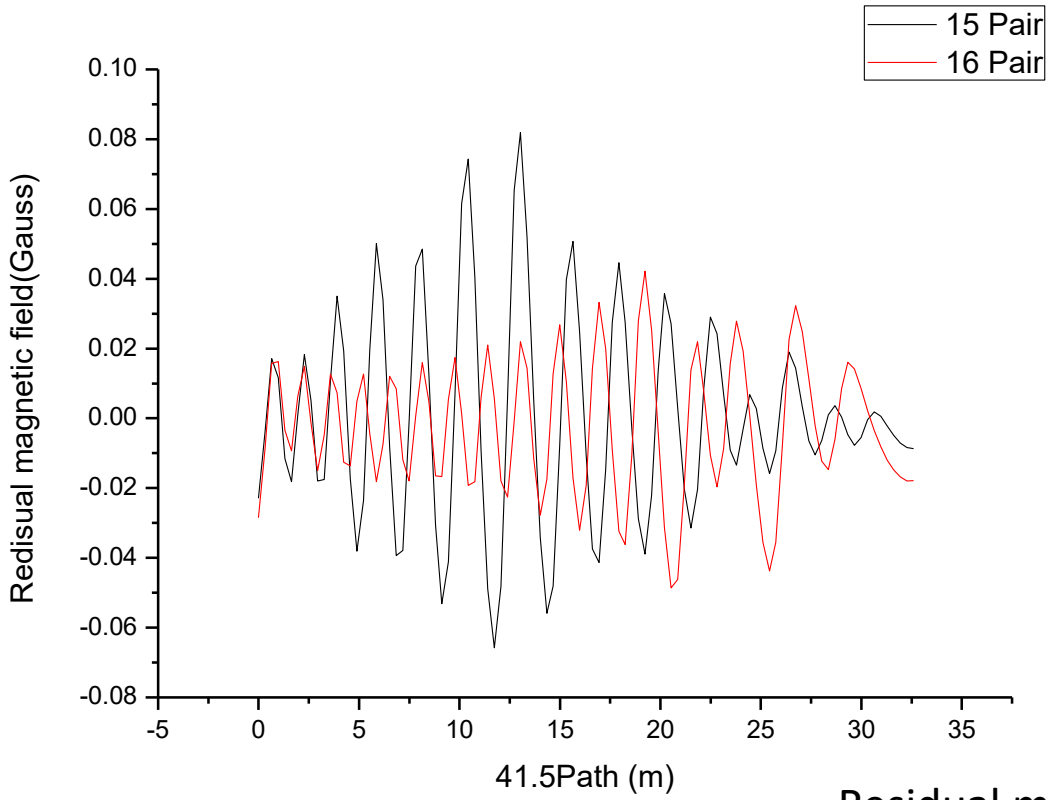
Residual magnetic field distribution

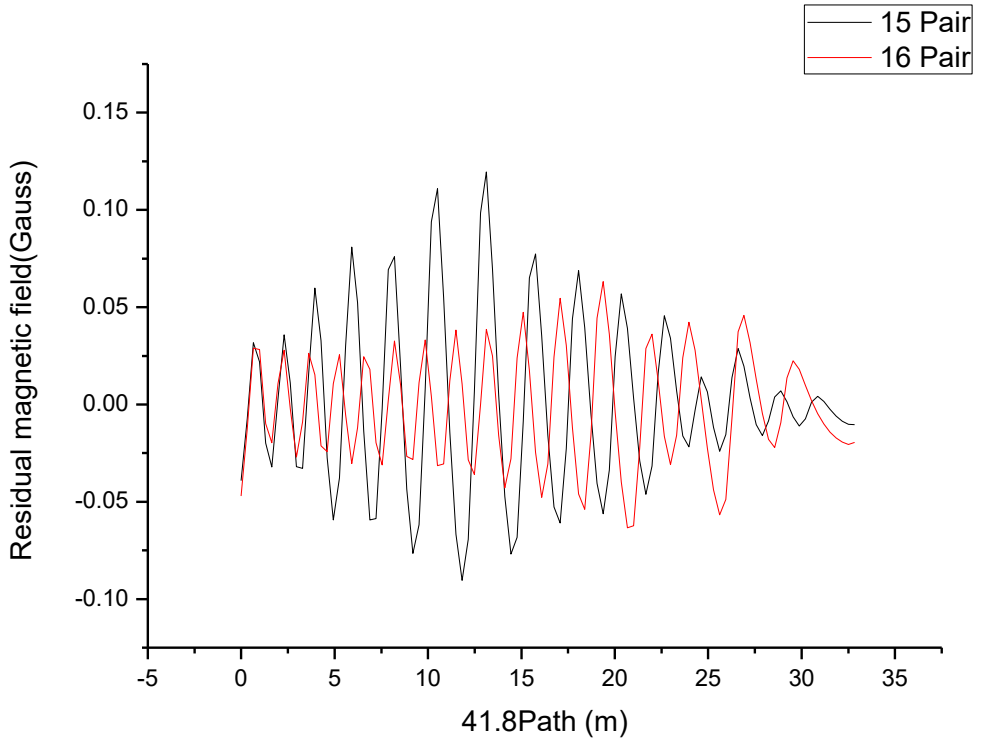
$$Deviation = \frac{|\ Max\ or\ Min\ |}{EMF} \times 100\%$$

EMF=0.44839 Gauss

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.0449	10.01
16 pairs	0.0314	7

41.5m and 41.8 ¼ sphere surface





Residual magnetic field distribution

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.0818	18.24
16 pairs	0.0486	10.84

	Absolute Max residual field (Gs)	Deviation (%)
15 pairs	0.1195	26.66
16 pairs	0.0634	14.14

comparison

Diameter (m)	**Max-to-EMF** deviation (%)	
	15 Pair	**16 Pair**
39	1.16	1.94
39.5	1.9	2.45
40	2.99	3.12
41	10.01	7
41.5	18.24	10.84
41.8	26.66	14.14

comparison

Peak-Peak deviation:

Diameter (m)	15 pairs of coil			16 pairs of coil		
	Maximum field strength(Gs)	Minimum field strength(Gs)	(**Max**$-$$\boldsymbol{Min}$)/EMF deviation (%)	Maximum field strength(Gs)	Minimum field strength(Gs)	(**Max**$-$$\boldsymbol{Min}$)/EMF deviation (%)
39	0.4536	0.4456	**1.78**	0.4495	0.4397	2.19
39.5	0.4570	0.4426	3.21	0.4508	0.4374	**2.99**
40	0.4618	0.4382	5.26	0.4531	0.4343	**4.19**
41	0.4933	0.4106	18.44	0.4688	0.4170	**11.55**
41.5	0.5302	0.3826	32.92	0.4906	0.3998	**20.25**
41.8	0.5679	0.3580	46.81	0.5116	0.3849	**28.26**

Summary

1. 20cm Install error can be accepted.
2. The plan of 16 pairs of coil seems much better than 15 pairs of coil.
3. Next, start the install error analysis of 16 pairs of coil, include coils move up and down, the radius increase and decrease, install angle of inclination.

Thanks