

WPT系统中的铁氧体磁性材料

冯则坤

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139-7146-8126

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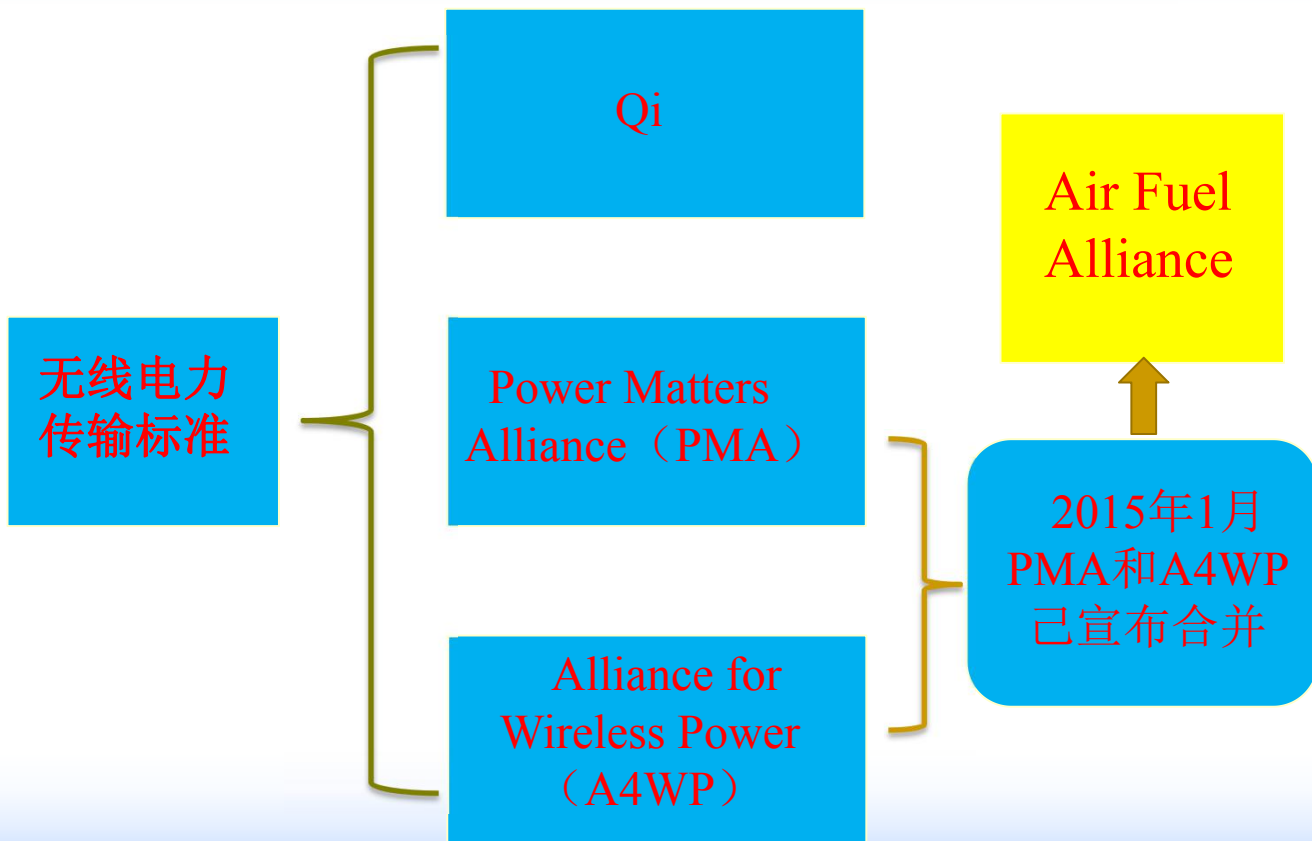


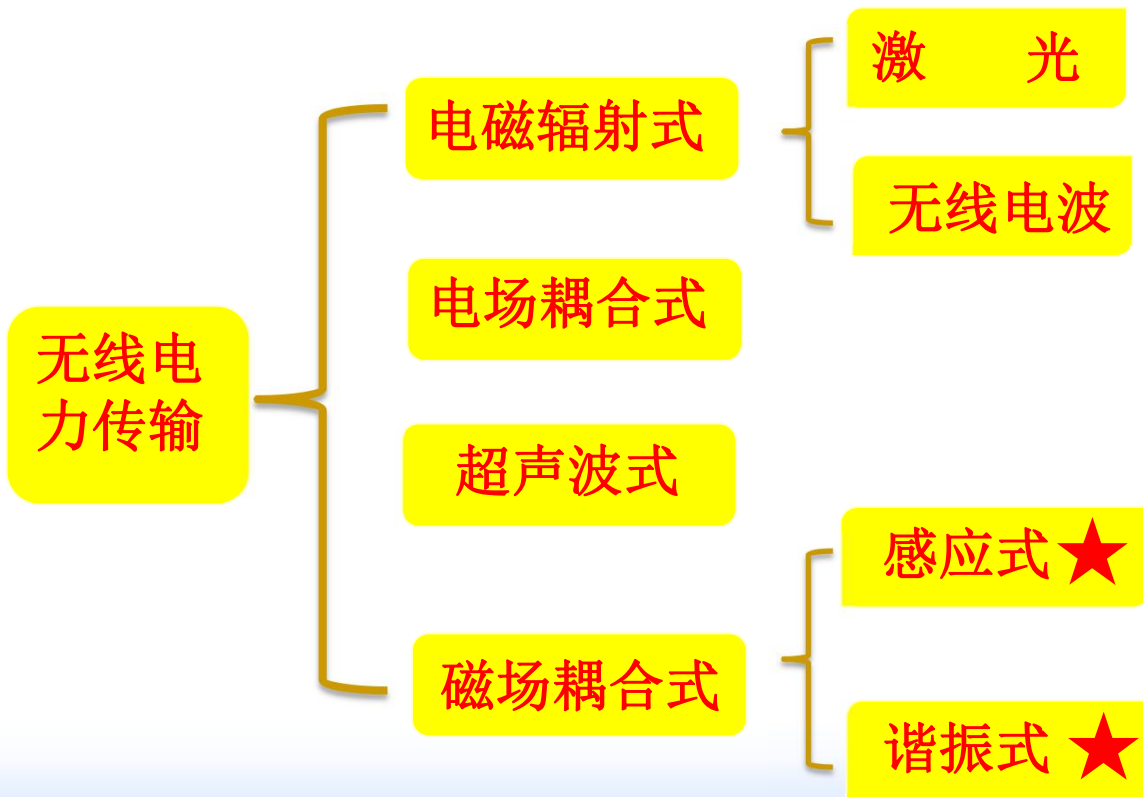


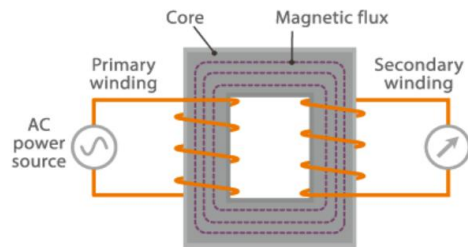
内 容 提 要

- ✓ WPT系统概要
- ✓ WPT系统中的铁氧体材料研发动向
- ✓ WPT系统中的铁氧体材料的作用
- ✓ WPT系统中的铁氧体材料研究
- ✓ 电动汽车WPT系统
- ✓ WPT系统中的铁氧体材料的发展
- ✓ 我们的工作

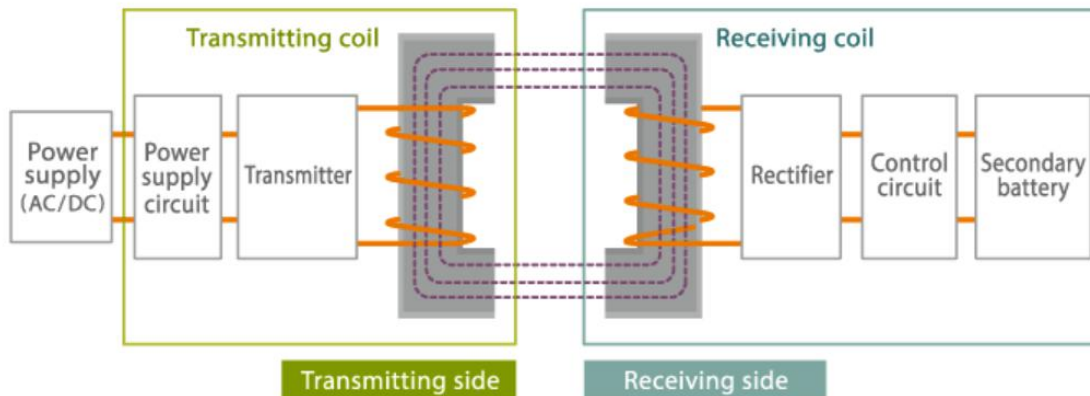
WPT系统概要

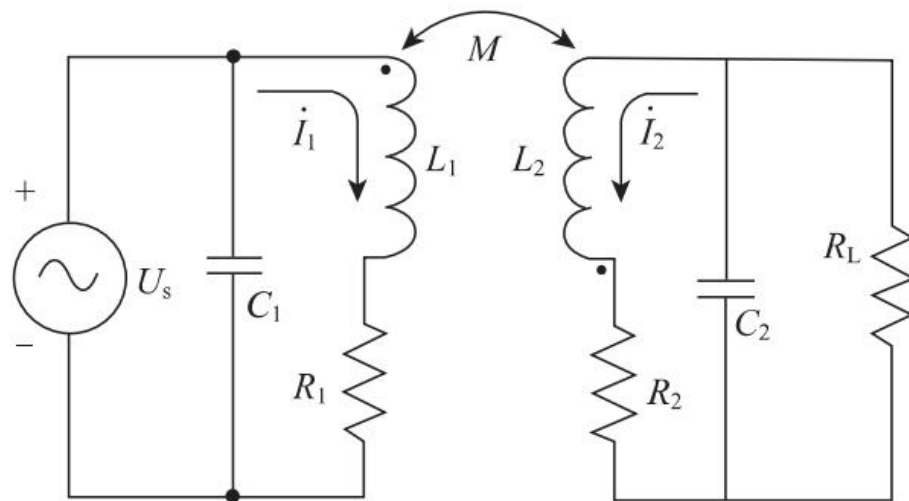






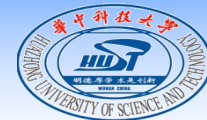
Wireless power transfer





四种主流 WPT 技术概述

实现方式	工作频率	相对传输距离	优点	缺点
磁感应耦合式	几十 kHz 至几百 kHz	几 mm 到几 m	原理简单, 容易实现, 传输功率大, 近距离传输效率高, 可高达 99%	漏磁损耗大, 传输距离短, 传输效率随传输距离的增大迅速减小, 对原副边铁心的形状和对齐方式要求高
磁耦合谐振式	几 MHz 至几十 MHz	几 cm 到几 m	效率高, 中等距离传输, 非辐射能量传输, 电磁辐射小, 谐振频率外的电磁干扰小	发射接收天线要求谐振频率相同, 容易出现误差, 传输功率仍不高
微波辐射式	通常采用 S、C 波段	几百 m 到几 km	高精度定向能量传输, 传输距离远, 传输过程中的大气损耗小	发射接收天线设计要求高, 传输效率不高, 能量利用效率低, 接收的功率信号较小
激光方式	常用波长约 800 nm	几十 m 到几 km	发散角较小, 定向性好, 能量密度更高, 会聚性更好, 发射接收口径小	在大气层内的传输损耗相对要大, 传输距离相对要短, 对准精度要求高, 技术不够成熟



ICNIRP GUIDELINES

International Commission for Non-Ionizing Radiation
Protection

国际非电离辐射防护委员会

ICNIRP规定，在0.3千赫至10兆赫的频率范围内，公众不应接触大于 $27\mu\text{T}$ 的通量密度。

GB 8702-2014 电磁环境控制限值

2014-09-23 发布 2015-01-01 实施

GB8702—2014

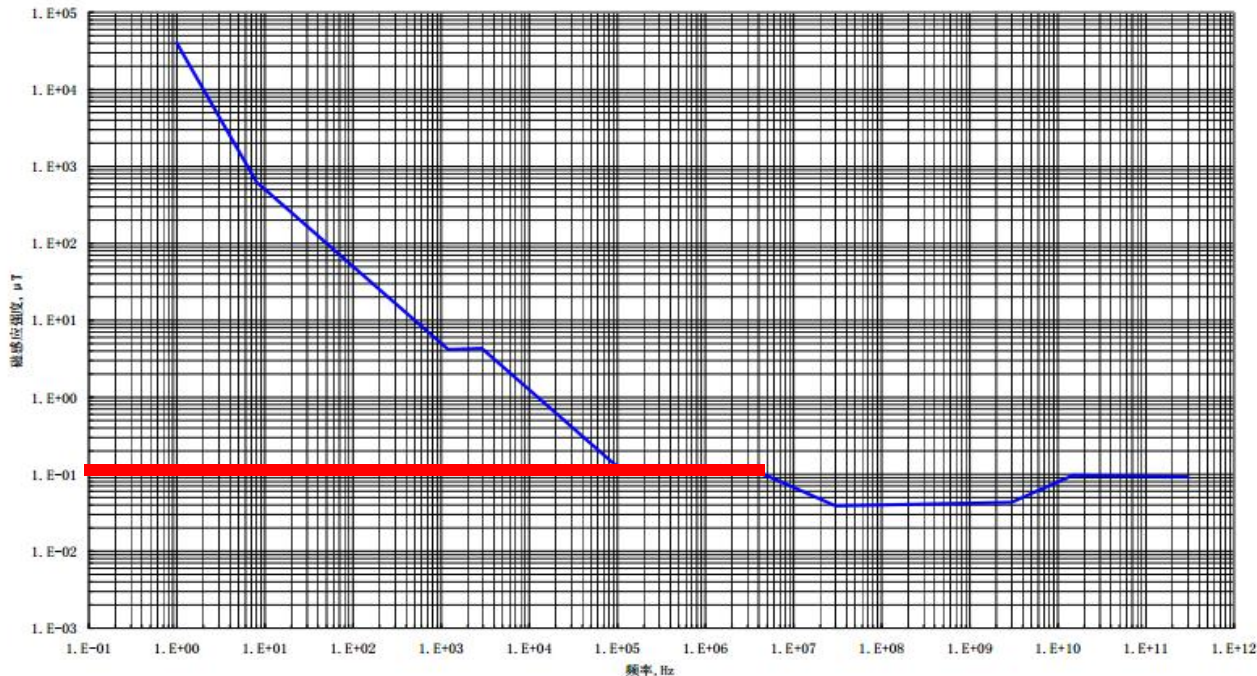


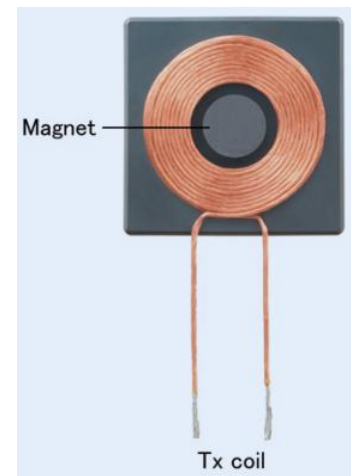
图2 公众暴露磁感应强度控制限值与频率关系

Qi标准中发射
线圈定位

主动定位型

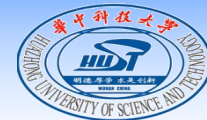
引导定位型

自由定位型









WPT系统中的铁氧体材料研发动向



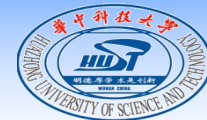
Wireless Power Transfer

Tx线圈单元和模组

搜索	目录/规格书 ?	图片	型号 ?	经销商的库存	型	用途	尺寸	符合WPC	输入电压 / V	输出功率	电感	直流电阻	备注
<input type="checkbox"/>			 WT1005690-12K2-A6-G	Buy Now	线圈单元	通用机械移动	100.0mm x 56.0mm	<input checked="" type="checkbox"/>	12	5W	11.5 to 12.5μH at 100kHz / 1Vrms	0.08Ω at 25°C	
<input type="checkbox"/>			 WT151512-22F2-ID	Buy Now	线圈单元	卫生保健耐磨	Φ15.3mm			Small Power (1W-3W)	6.8μH at 100kHz / 1Vrms	0.18Ω at 25°C	小型
<input type="checkbox"/>			 WT202012-15F2-ID	Buy Now	线圈单元	卫生保健耐磨	Φ20.3mm			Small Power (1W-3W)	6.2μH at 100kHz / 1Vrms	0.095Ω at 25°C	小型
<input type="checkbox"/>			 WT303012-12F2-ID	Buy Now	线圈单元	卫生保健耐磨	Φ30.0mm			Small Power (1W-3W)	6.3μH at 100kHz / 1Vrms	0.115Ω at 25°C	小型
<input type="checkbox"/>			 WT505090-10K2-A11-G	Buy Now	线圈单元	通用机械移动	Φ50.0mm	<input checked="" type="checkbox"/>	5	5W	6.3μH at 100kHz / 1Vrms	0.06Ω at 25°C	
<input type="checkbox"/>			 WT505090-20K2-A10-G	Buy Now	线圈单元	通用机械移动	Φ50.0mm	<input checked="" type="checkbox"/>	19	5W	24μH at 100kHz / 1Vrms	0.1Ω at 25°C	
<input type="checkbox"/>			 WT525225-20K2-A1-G	Buy Now	线圈单元	通用机械移动	52.0mm x 52.0mm	<input checked="" type="checkbox"/>	19 / 12	5W	24μH at 100kHz / 1Vrms	0.1Ω at 25°C	
<input type="checkbox"/>			 WTM505090-10K2-5V-G1	Buy Now	模组	通用机械移动	Coil unit:Φ50.0mm, Module:Φ53.0mm	<input checked="" type="checkbox"/>	4.75 to 5.2	5W	6.3μH at 100kHz / 1Vrms	0.06Ω at 25°C	

Rxコイルユニット(WFC準拠)

製品写真	シリーズ・タイプ	寸法 (mm)	効率 (%)	インダクタンス (μH)	直流抵抗 (Ω)	製品カタログ	品番リスト
	WR303050-15F5-G	30.0×29.6	66	12.3 at 100kHz	0.41 at 25° C	162KB	
	WR444025-17M6-G	43.5×39.5	68	16.7 at 100kHz	0.65 at 25° C	159KB	
	WR444030-16F3-G		70	19.0 at 100kHz	0.70 at 25° C	159KB	
	WR483245-15F5-G	48.2×32.2	72	13.0 at 100kHz	0.20 at 25° C	166KB	
	WR483265-15F5-G		73	13.3 at 100kHz		164KB	



Wireless Power Transfer



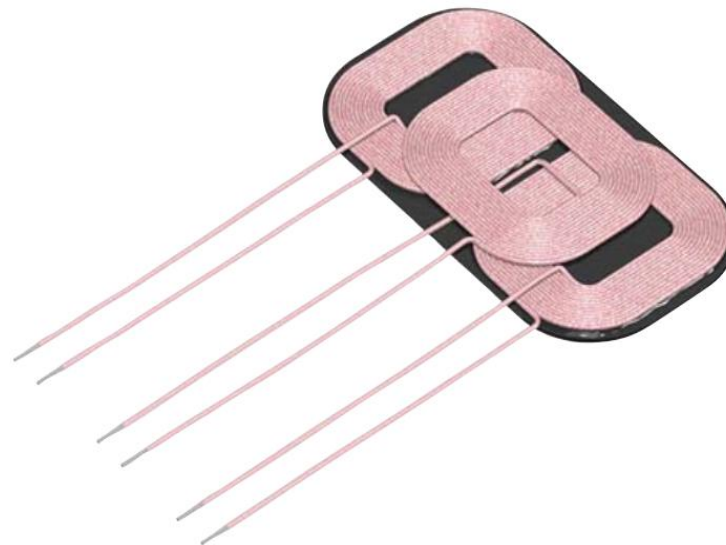
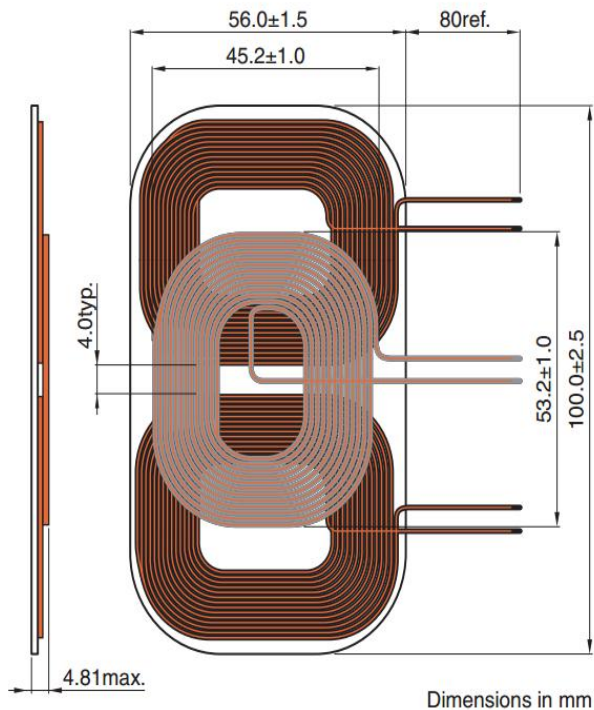
January 2017

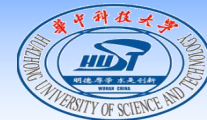
ワイヤレス給電コイルユニット

Txコイルユニット (WPC準拠)

WT1005690-12K2-A6-G

■ 形状と寸法





Wireless Power Transfer



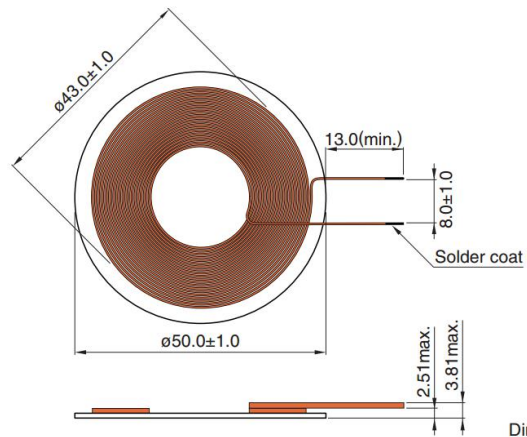
January 2017

ワイヤレス給電コイルユニット

Txコイルユニット (WPC準拠)

WT505090-10K2-A11-G

■ 形状と寸法



Dimensions in mm

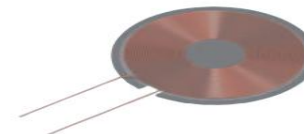
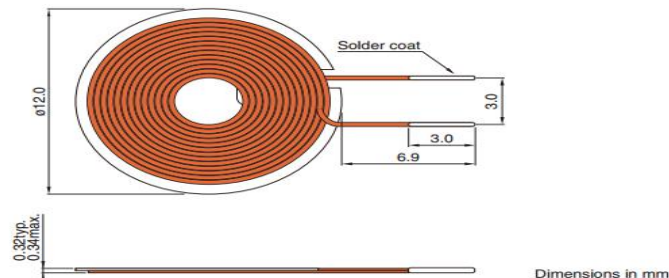


无线充电 小型Rx (接收) 线圈单元

RoHS指令对应产品
无卤素

WR121210-27M8-ID的概要

■ 形状和尺寸



■ 电气特点

□ 特点规格表

LxW 尺寸 (mm)	厚度 (mm)max.	电感 [100kHz, 1Vrms] (μ H)	电阻值 [100kHz, 1Vrms] (Ω)	型号
ϕ 12	0.34	8.32	0.98	WR121210-27M8-ID

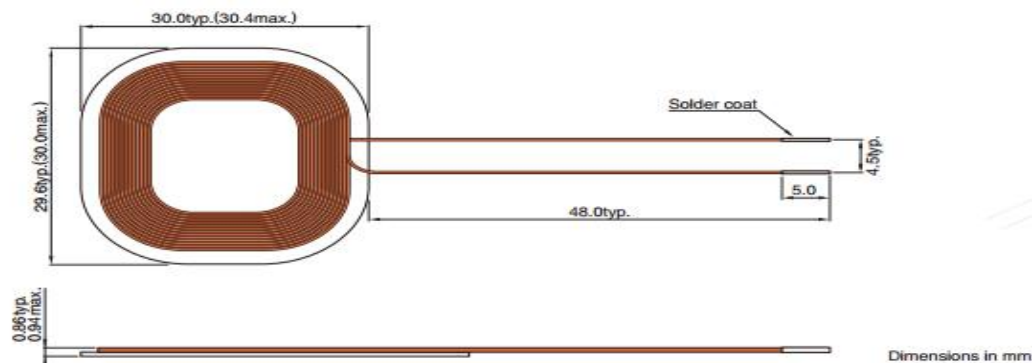
无线充电

小型Rx (接收) 线圈单元

RoHS指令对应产品
无卤素

WR303050-12F5-ID的概要

■ 形状和尺寸



■ 电气特点

□ 特点规格表

LxW 尺寸 (mm)	厚度 (mm)max.	电感 [100kHz, 1Vrms] (μ H)	电阻值 [100kHz, 1Vrms] (Ω)	型号
30x29.6	0.94	8.23	0.28	WR303050-12F5-ID

* 更多信息请咨询我们。

★ ⊕ 戸田工業株式会社

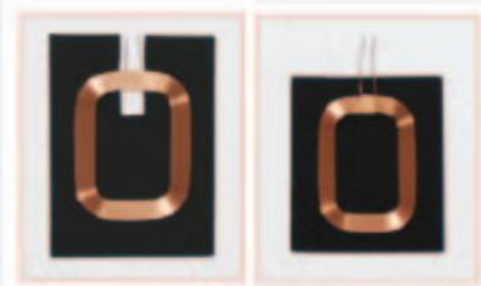
無線充電用アンテナ&パーツ

RX・TX用アンテナ/ Shield Material/Coil Parts

～ 薄くて効率の高い無線充電アンテナの限界に挑戦 ～

製品
情報

Receiver Parts (RX)



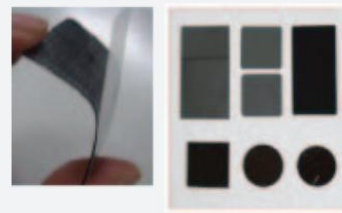
Transmitter Parts (TX)



Coil Parts



Shield Material



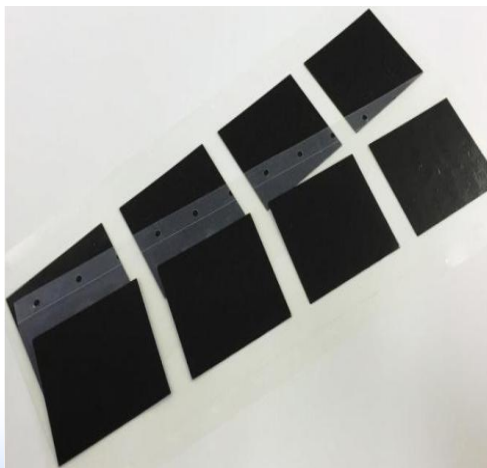
Specification:Shield Material

Application part	TYPE	μ'	THICKNESS (mm)	SIZE (Example) (mm)
RX	Metal Polymer	45 ~ 230	0.1 ~ 0.3	300x 200
	Flexible	100 ~ 500	0.05 ~ 0.45	LARGE SIZE 135x 135 CUT SIZE 48x32 2x15
TX	Hard	150 ~ 3,200	0.6 ~ 2.5	39x27 48x32 52x52 ϕ 44

A6 A1 A11 Type (TX Parts)

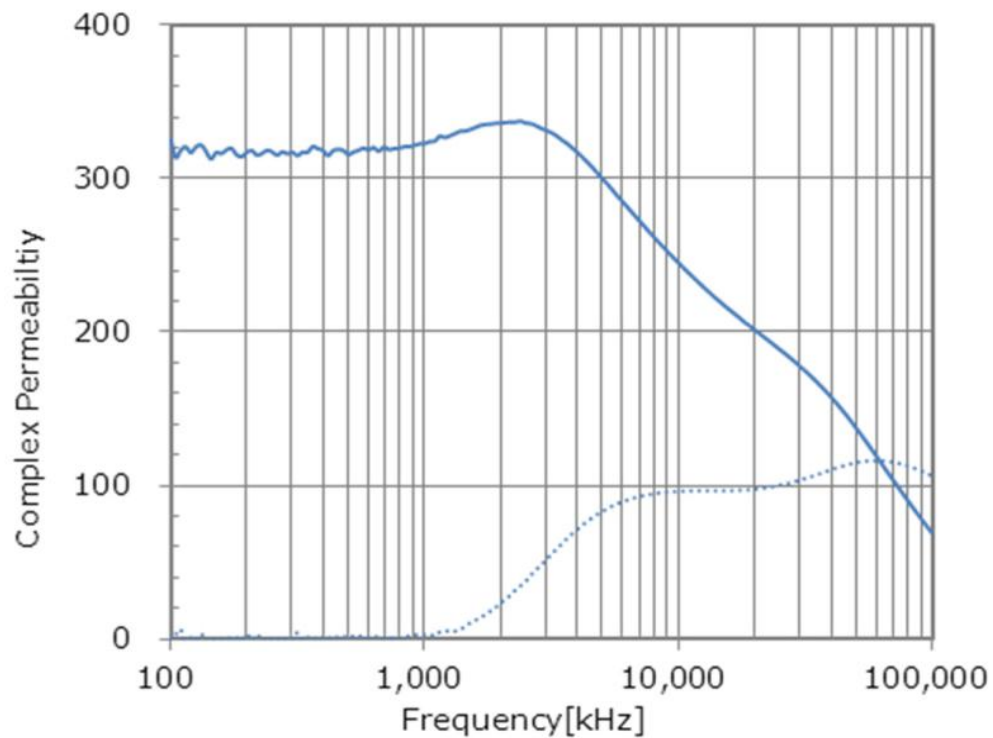
TYPE	SIZE (mm)	LEFT COIL			CENTER COIL			RIGHT COIL		
		L(μ H)	R(m Ω)	Q	L(μ H)	R(m Ω)	Q	L(μ H)	R(m Ω)	Q
A6	106x 53x 4.6t	12.5	85.5	91	12	71.6	102.5	12.5	85.5	91
A1	52x 52x 3.0t	-	-	-	24 \pm 10%	180(typ)	90(typ)	-	-	-
A11	52x 52x 3.0t	-	-	-	6.3 \pm 10%	45(typ)	80(typ)	-	-	-

Mn-Zn Ferrite Sheet for Wireless Power Charger



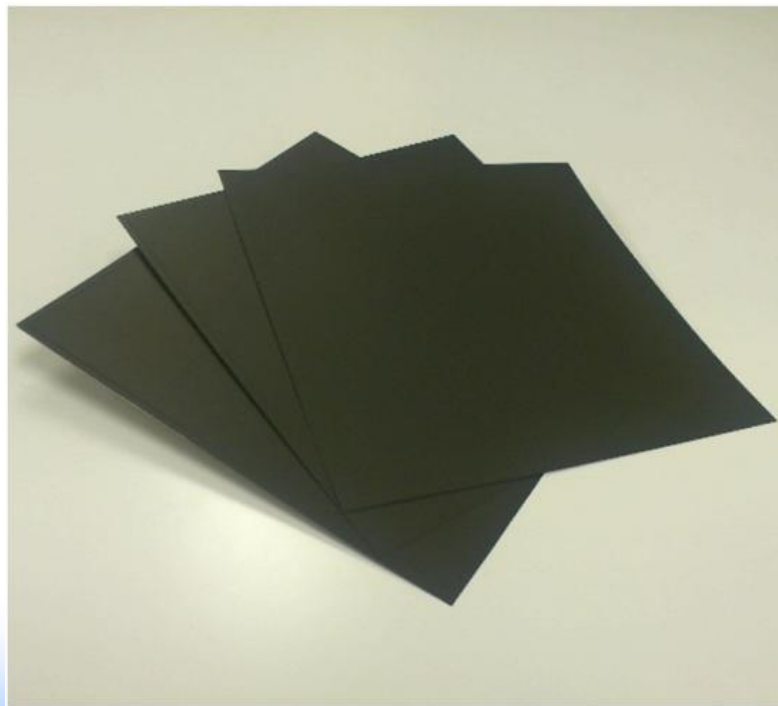
GRADE	FLX-W01 Serieese
Material	Mn-Zn Ferrite
Max Size (mm)	50 X 45
Thickness (mm)	0.2~0.6
μ' @100kHz	330
Environment	RoHS / Halogen free

Frequency vs Permeability



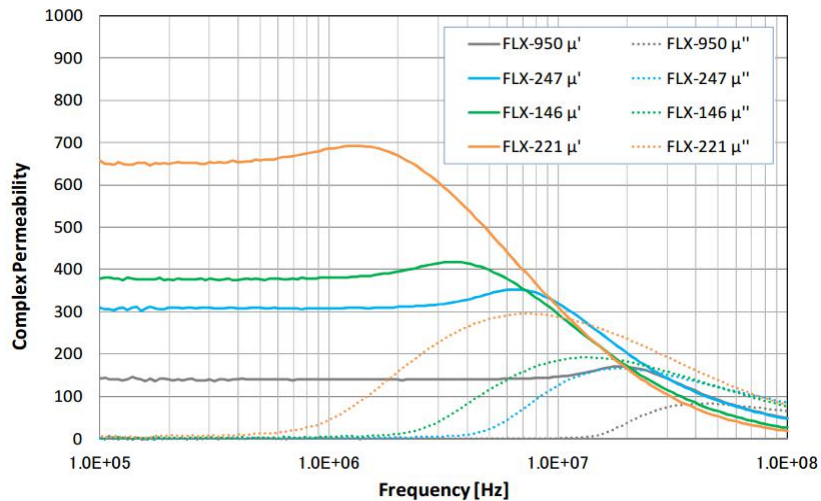
>>>>FLEXIBLE FERRITE SHEET

WPC / Wireless Power Charger



GRADE	FLX-950	FLX-247	FLX-146	FLX-221
Material	Ni-Zn-Cu Ferrite	←	←	←
Max. Size (mm)	135X135	135X135	135X135	135X135
Thickness (mm)	0.05~0.30	0.05~0.30	0.05~0.30	0.05~0.30
μ' @100kHz	140	310	380	660
Curie Temp.(°C)	215	210	150	100
Environment	RoHS/Halogen free	RoHS/Halogen free	RoHS/Halogen free	RoHS/Halogen free

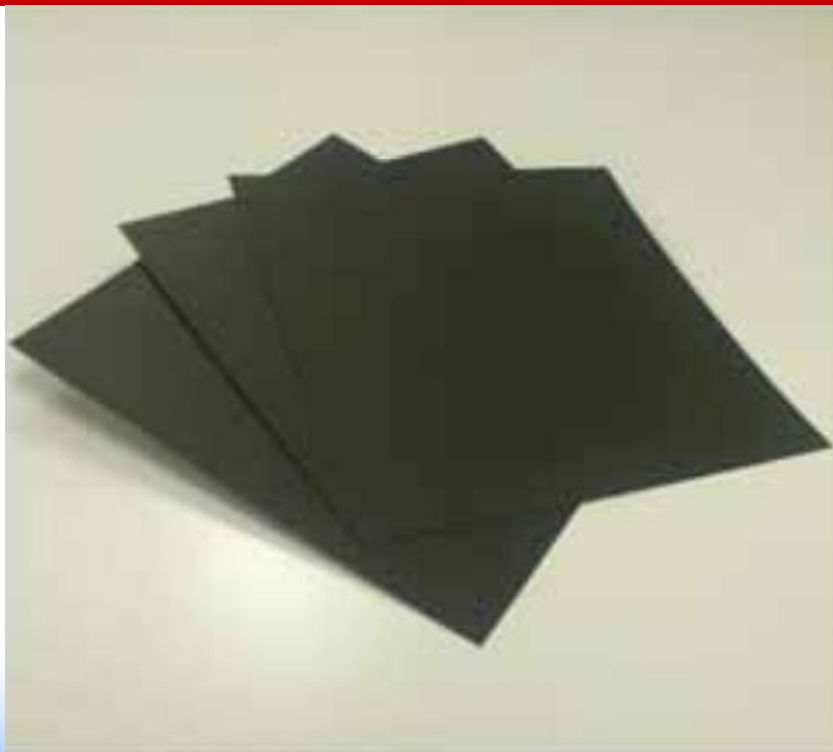
Frequency vs Permeability

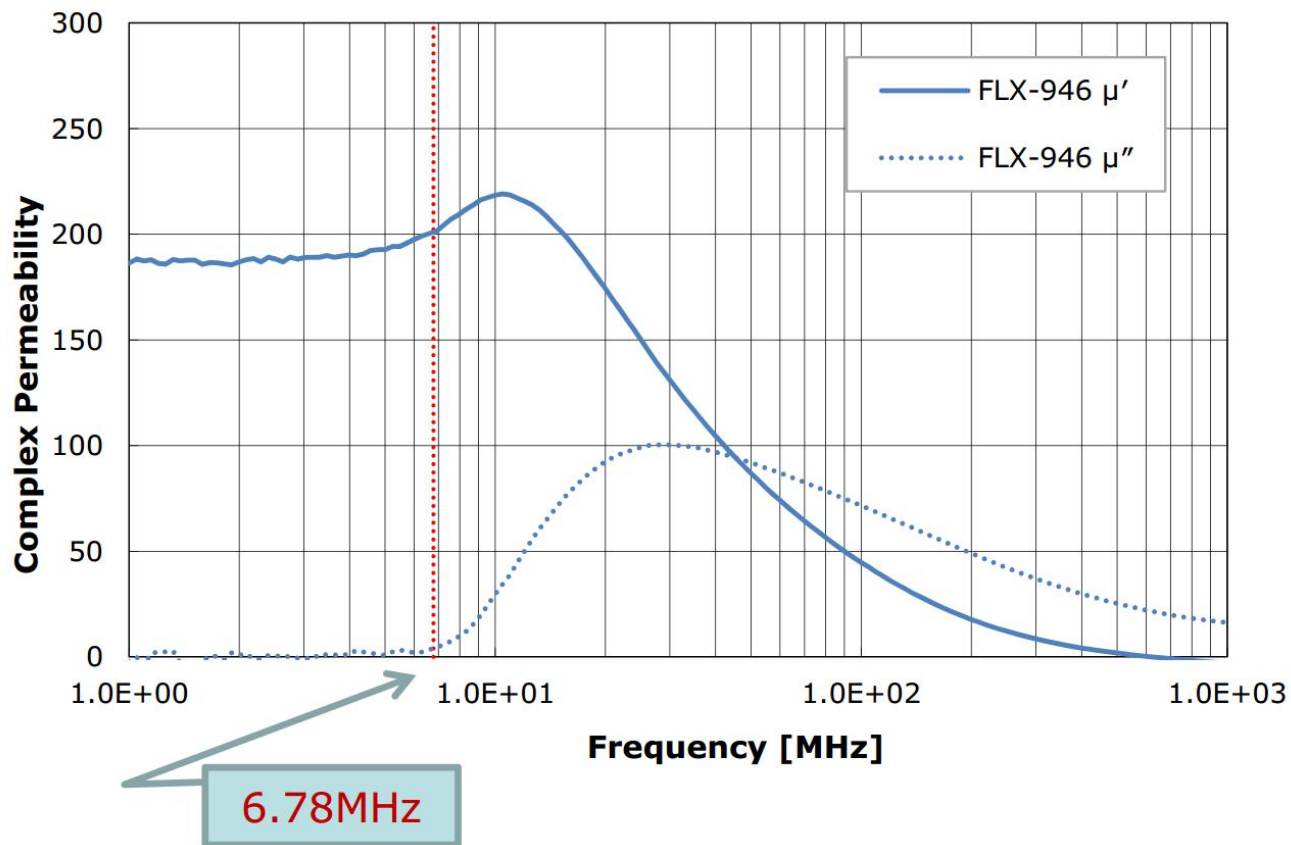


>>>>FLEXIBLE FERRITE SHEET

For A4WP @ 6.78MHz

A4WP / FLX-946 Series
Alliance for Wireless Power





GRADE	FLX-946
Material	Ni-Zn-Cu Ferrite
Max. Size (mm)	135X135
Thickness (mm)	0.05~0.30
μ' @6.78MHz	200
μ'' @6.78MHz	5
Environment	RoHS/Halogen free

FLEXIBLE FERRITE SHEET

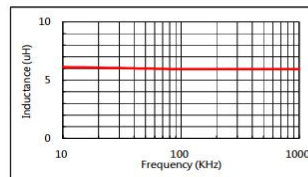
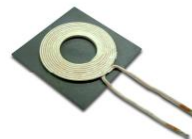
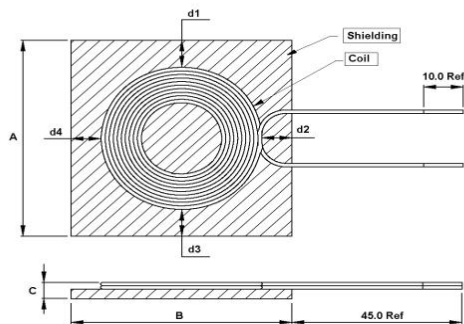
Specification

Grade	FLX-Z01-110HM10B10			
Ferrite plate	Permeability @100kHz	Size W [mm]	Size L [mm]	Thickness [mm]
	u'			
	660	125	125	0.110
Tolerance	+/-15%	min.	min.	+/-10%
Construction		Type	Color	Thickness [mm]
Polyester film tape (PET)		Matte	Black	0.010
Ferrite Plate				0.110
Double Coated Adhesive tape (ADH)			Black	0.010
Release Liner		PET		0.075
Total Thickness (not include release liner)				0.130
Tolerance				+/-10%



冠磁企業股份有限公司

Power Transmitter - TX11S (WPC V1.1 design A11 : 5V / 110-205KHz)



Dimension :	unit	mm
A		53.0 +- 1.0
B		53.0 +- 1.0
C		3.8 max
d1~d4		2.0 min

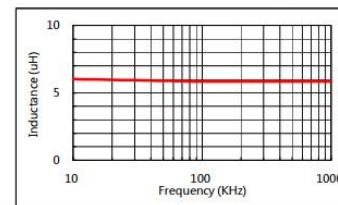
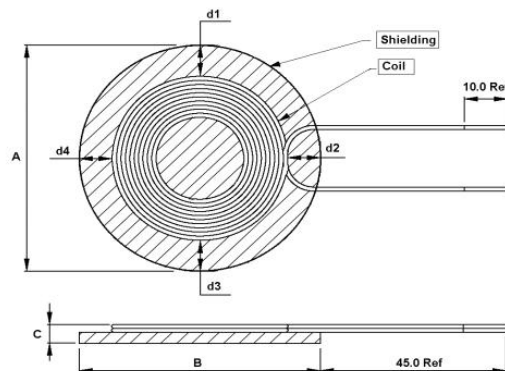
Electronic Characteristics :	L	6.1uH +- 10%
	DCR	20 mΩ ref
Test Instruments :	Microtest 6377	
Test Conditions :	100KHz / 1.0V / 0A	



CROWN FERRITE ENTERPRISE CO.

<http://www.cfe.com.tw> e-mail : crownco@cfe.com.tw

Power Transmitter - TX11C (WPC V1.1 design A11 : 5V / 110-205KHz)



Dimension :	unit	mm
A		52.5 +- 1.0
B		52.5 +- 1.0
C		3.8 max
d1~d4		2.0 min

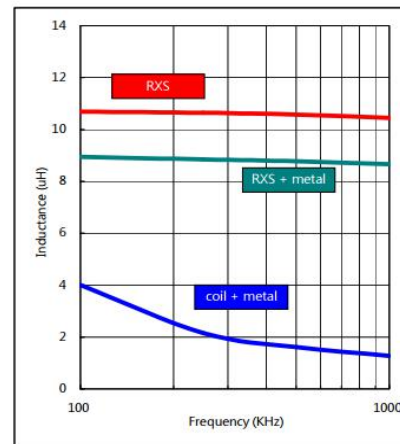
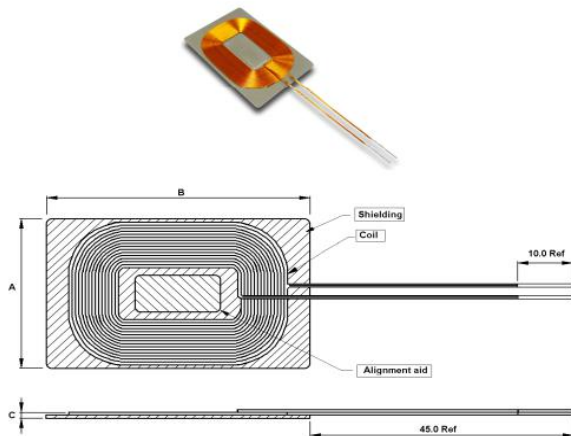
Electronic Characteristics :	L	6.0uH +- 10%
	DCR	20 mΩ ref
Test Instruments :	Microtest 6377	
Test Conditions :	100KHz / 1.0V / 0A	



CROWN FERRITE ENTERPRISE CO.

<http://www.cfe.com.tw> e-mail : crownco@cfe.com.tw

Power Receiver - RXS



Dimension :	unit	mm
A		48.0 +- 0.4
B		32.0 +- 0.3
C		1.1 max

Electronic Characteristics :	L	10.8uH +- 10%
	DCR	200 mΩ ref
Test Instruments :	Microtest 6377	
Test Conditions :	100KHz / 1.0V / 0A	



3M™ Flux Field Directional Material EM60TF Series

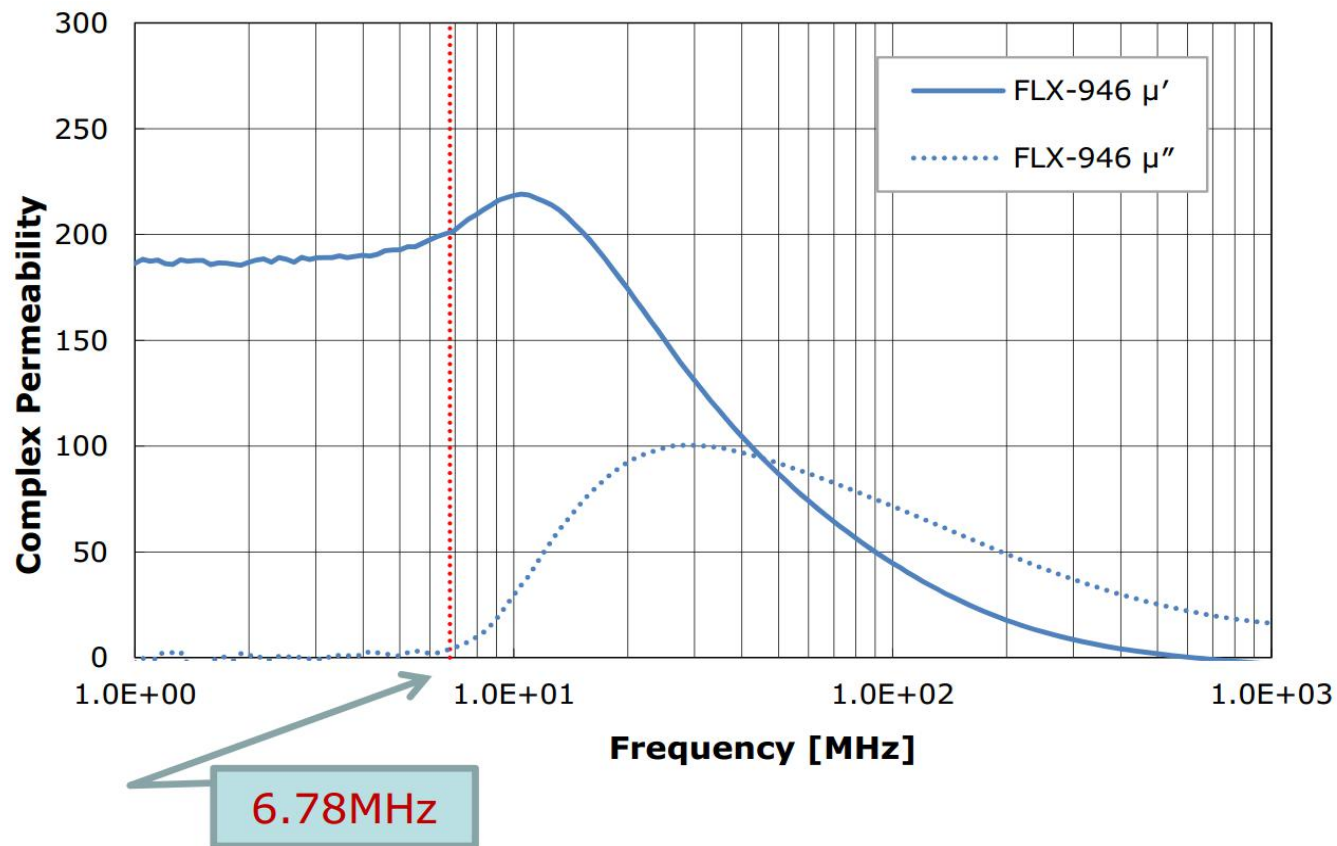
3M™ Flux Field Directional Material EM60TF*				
Product	Cover	Thickness (mm)		
		Magnetic	PSA	Total
EM60TF-006	0.010/0.020 (Customized thickness are available)	0.040	0.010/0.020 (Customized thickness are available)	0.060
EM60TF-008		0.060		0.080
EM60TF-009		0.070		0.090
EM60TF-010		0.080		0.100
EM60TF-012		0.100		0.120
EM60TF-014		0.120		0.140
EM60TF-024		0.200		0.240
EM60TF-034		0.300		0.340

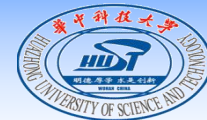
*Typical tolerance of each thickness: +/- 10 %

3M™ Flux Field Directional Material EM60TF	
Property	Method*
Type of Absorber Material	Sintered Ferrite Sheet
Magnetic Permeability*	600 (at 1 MHz)
Standard Size (mm)	125 x 125
Resistivity** (Ω meter)	10^4
Operating Temperature ($^{\circ}\text{C}$)	-30 ~ +85

*This value was measured with Agilent E4991A RF Impedance/Material Analyzer. (Fig. 1)

**Tested in accordance with ASTM D257 test method.

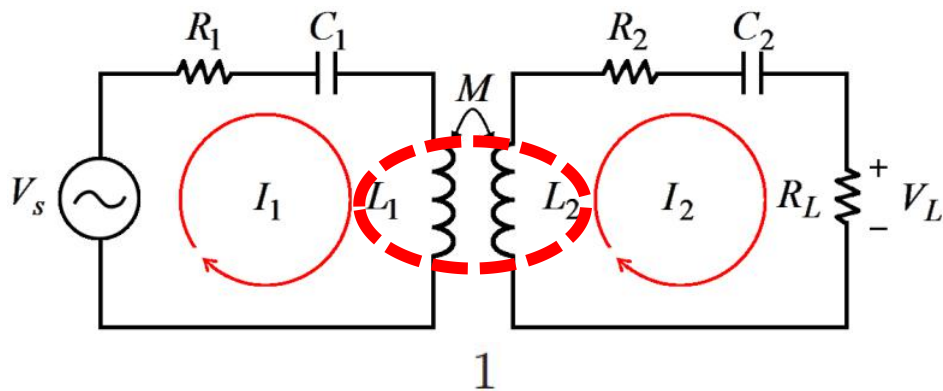




WPT系统中铁氧体材料的作用



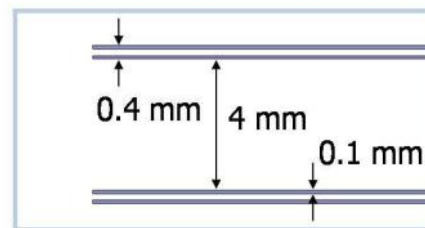
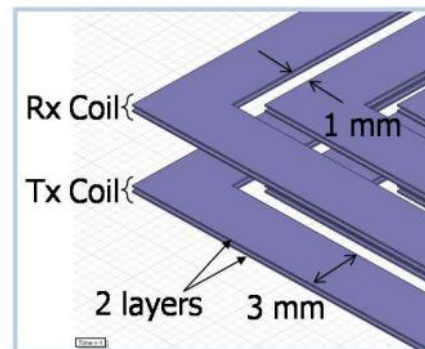
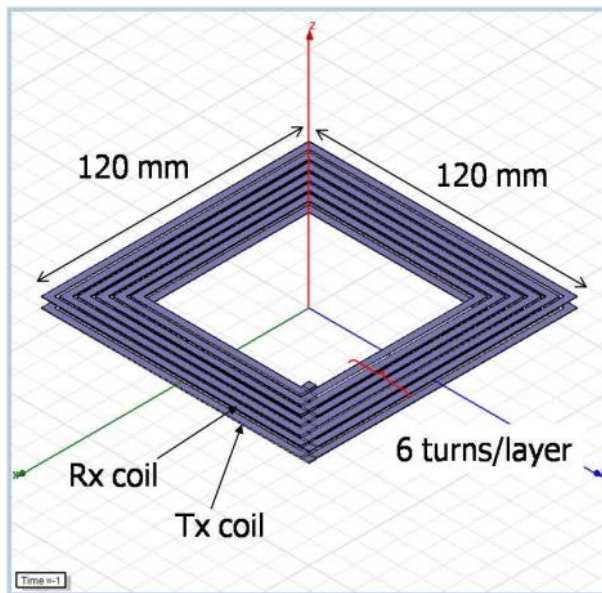
Optimized shield design for reduction of EMF from wireless power transfer systems



$$\eta \approx \frac{1}{1 + R_1 R_L / (\omega M)^2}$$

KAIST

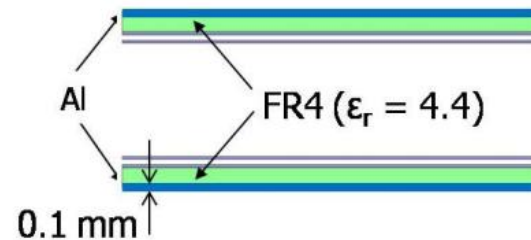
Samsung Electronics, Co. LTD.



Current at the Tx coil is 4.5 A with a frequency of 100 kHz

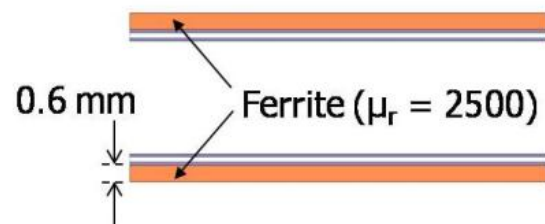
Rx Coil {

Tx Coil {

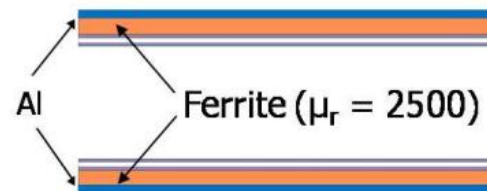


(a)

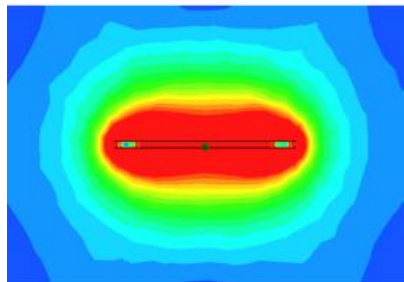
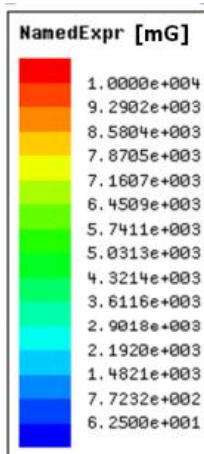
(b)



(c)



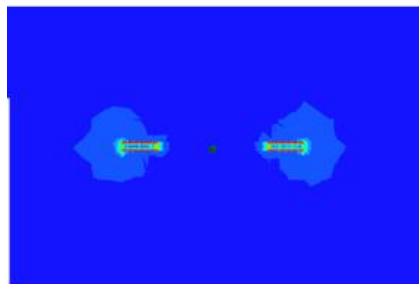
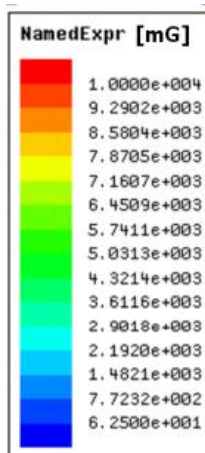
(d)



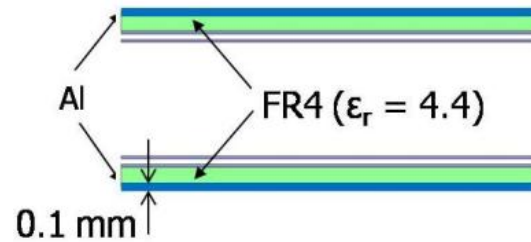
(a)



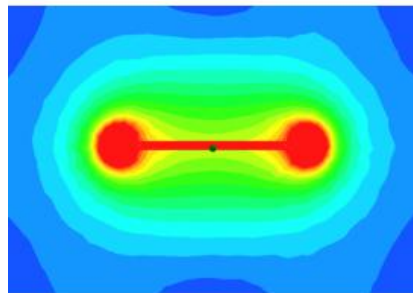
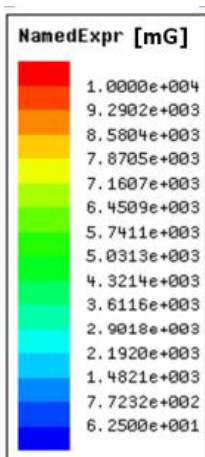
(a)



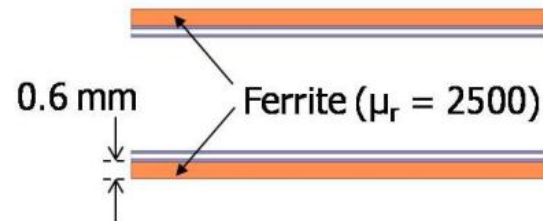
(b)



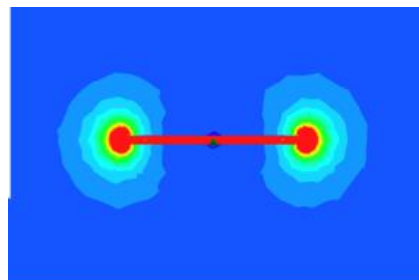
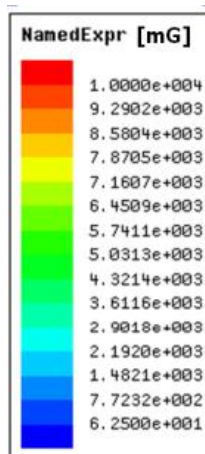
(b)



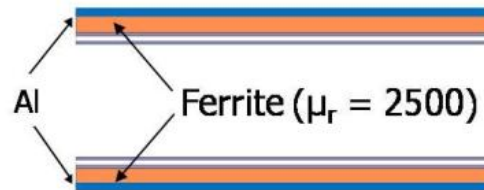
(c)



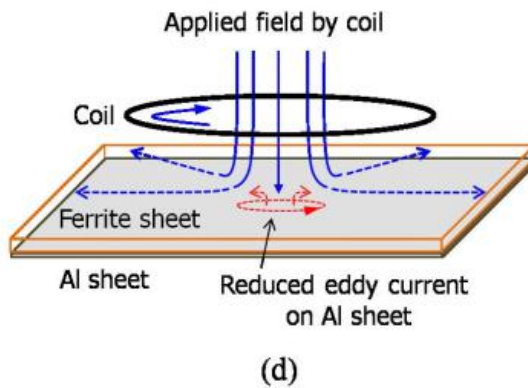
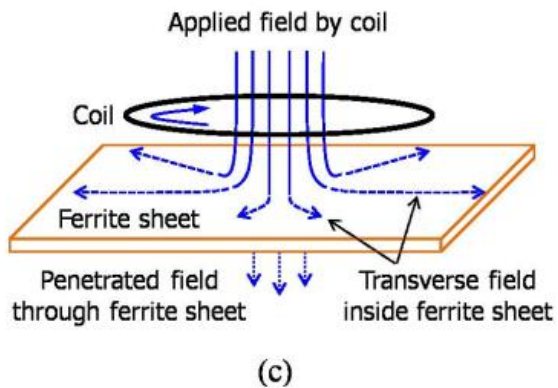
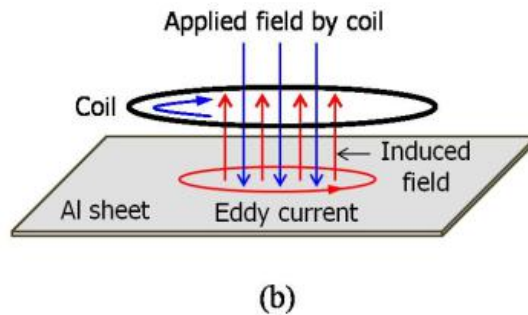
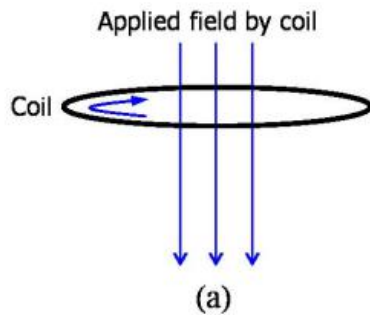
(c)



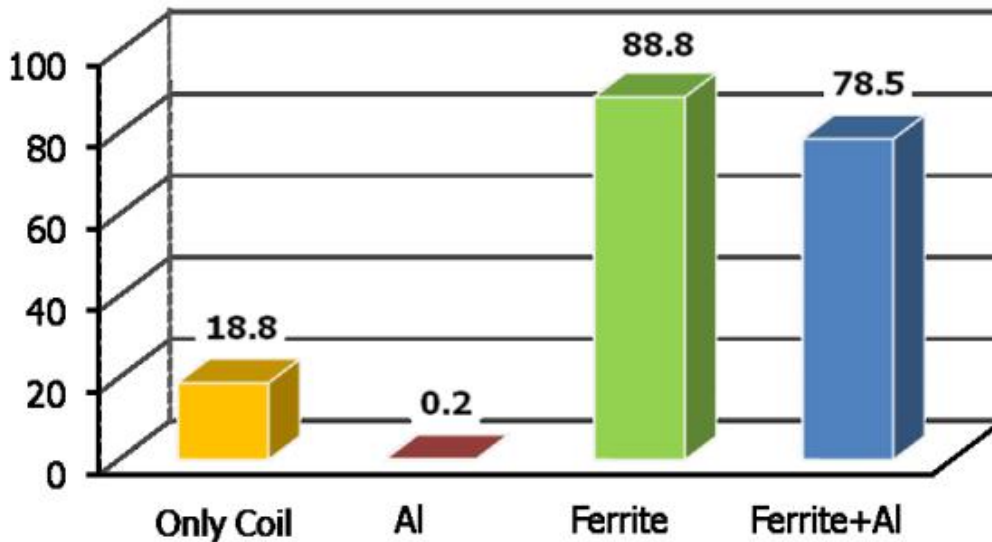
(d)



(d)



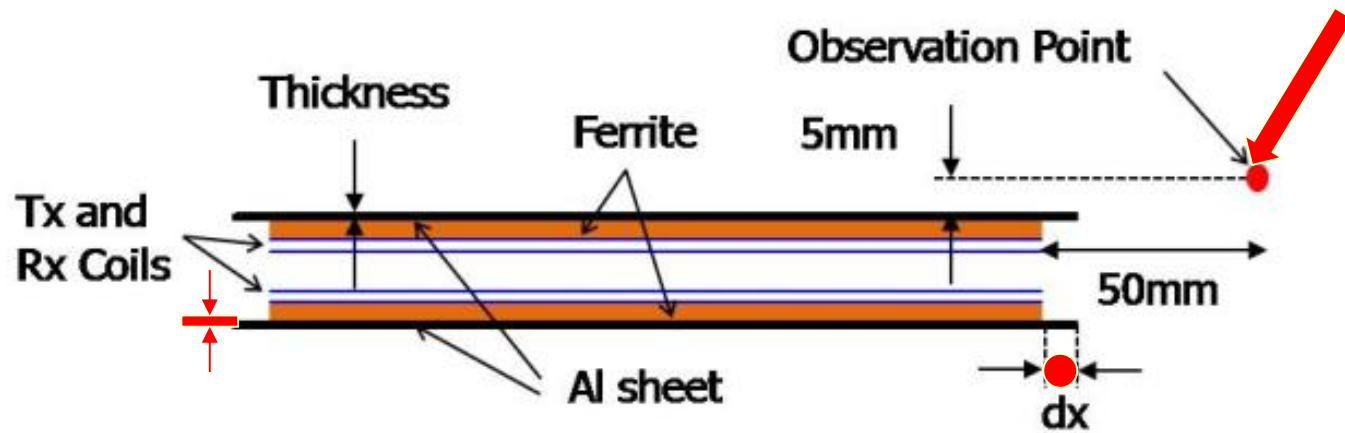
Mutual Inductance (μH)

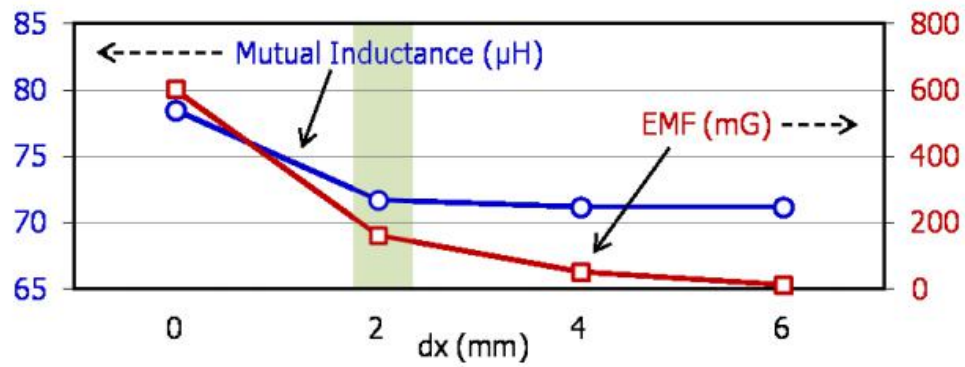


$$\eta_{\text{ferrite}} = \frac{1}{1 + A/M^2}$$

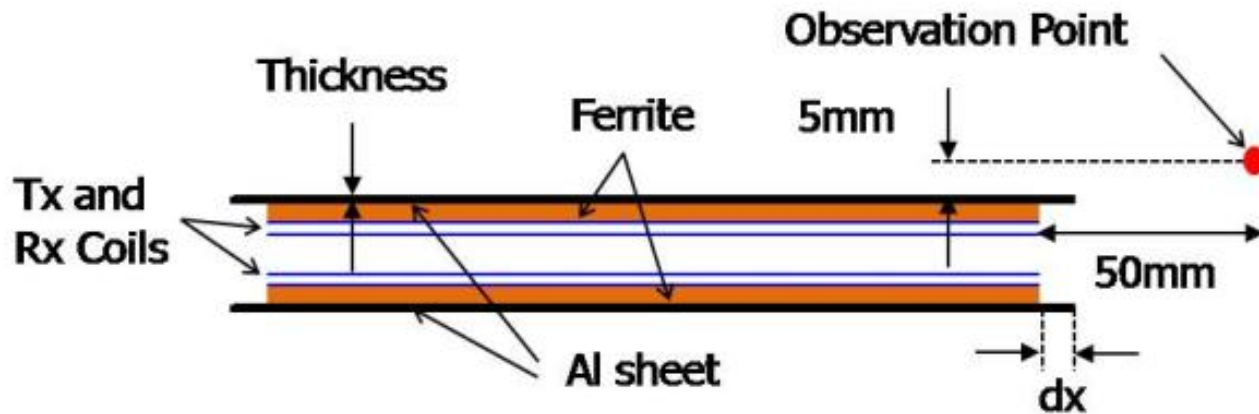
$$A = R_1 R_L / \omega^2$$

$$\eta_{\text{ferrite-Al}} = \frac{1}{1 + 1.28A/M^2}$$

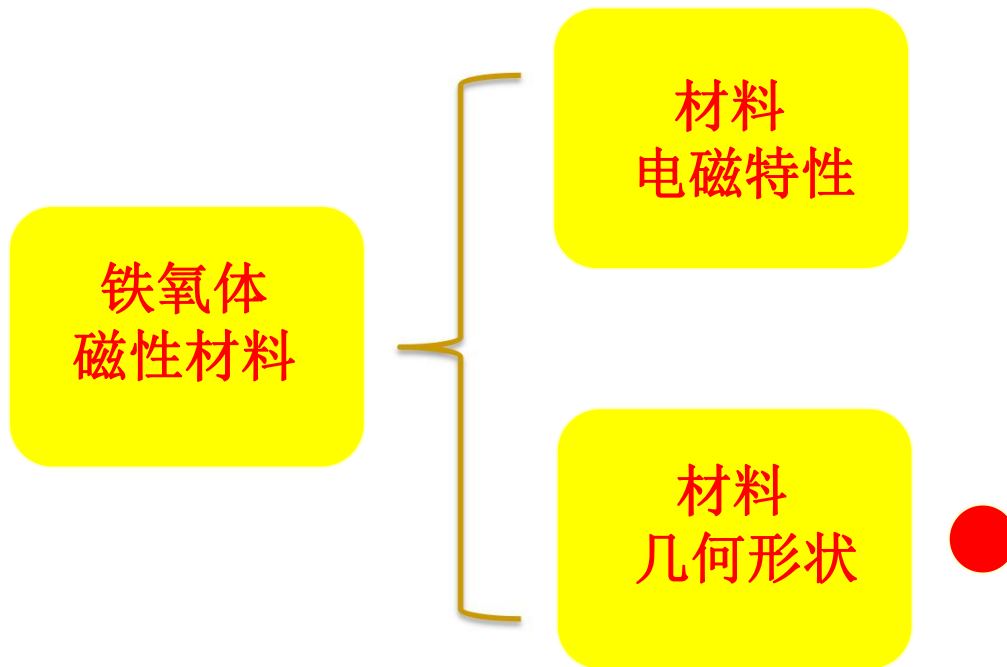




(a)

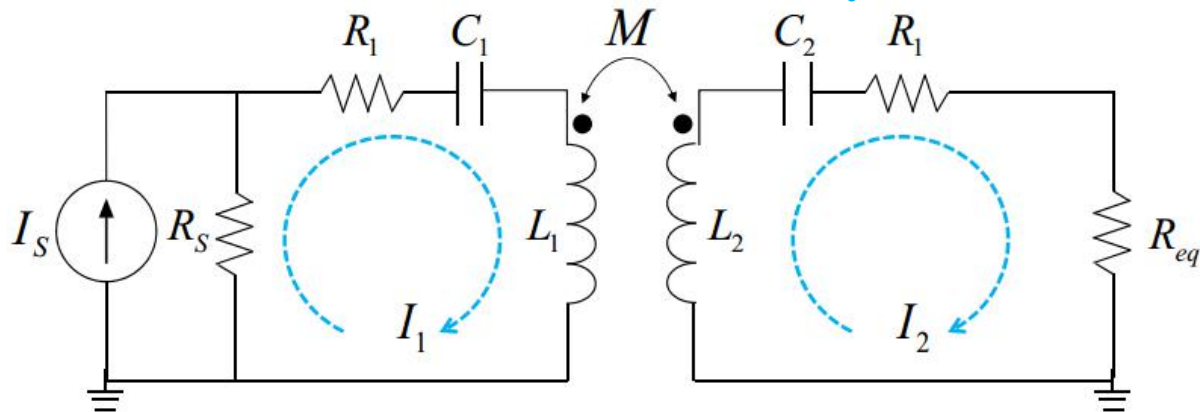


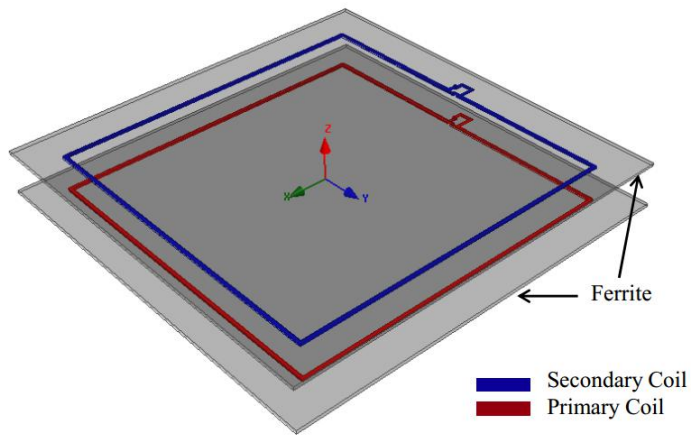
WPT系统中铁氧体材料研究



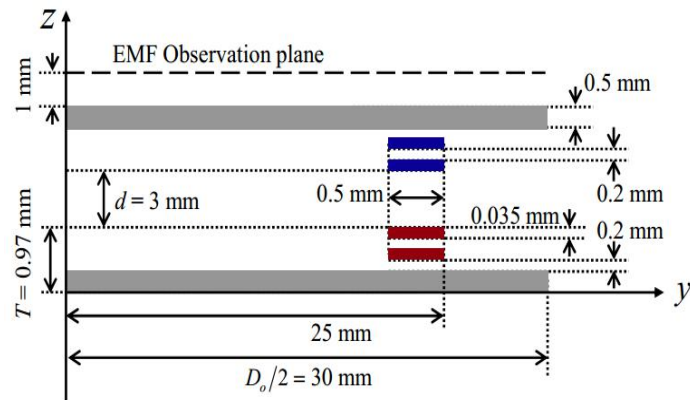
材料电磁参数

Optimization Procedure of Complex Permeability for a Wireless Power Transfer System





(a)



(b)

DESIGN CONSTRAINTS

Parameter	Symbol	Value
Load Power	P_L	6 W
Equivalent Load Resistance	R_{eq}	15 Ω
Outer Diameter of a Coil	D_o	≤ 60 mm
Total Thickness of a Coil	T	≤ 1 mm
Air Gap between Coils	d	3 mm

DESIGN REQUIREMENTS

Parameter	Symbol	Value
Transfer Efficiency	η_R	≥ 90 %
EMF	-	minimum

MAGNETIC PROPERTIES OF CANDIDATE SHEET-TYPE FERRITES

Index	μ'_r	μ''_r	$\tan \delta$
1	31	2	0.0645
2	110	20	0.1818
3	150	30	0.2
4	100	0.69	0.0069
5	142	1.54	0.0108
6	171	2.81	0.0164
7	95	0.54	0.0057
8	130	4.06	0.0312
9	260	45	0.1731
10	100	50	0.5

SIMULATION RESULTS OF IMPEDANCES AND EFFICIENCY

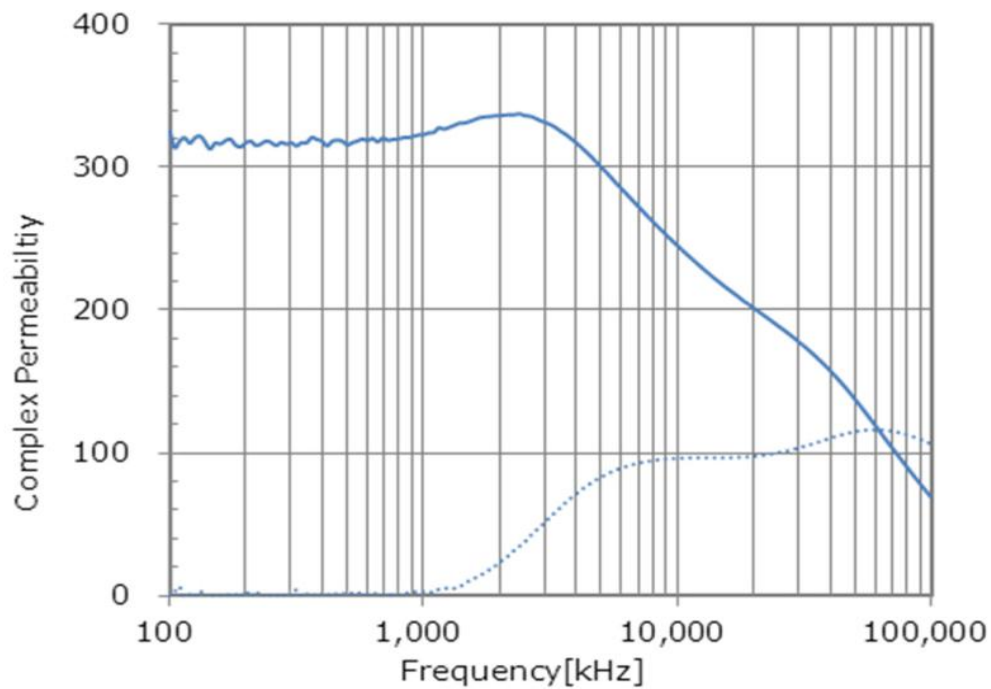
:

ARRANGED IN DESCENDING ORDER OF η_0

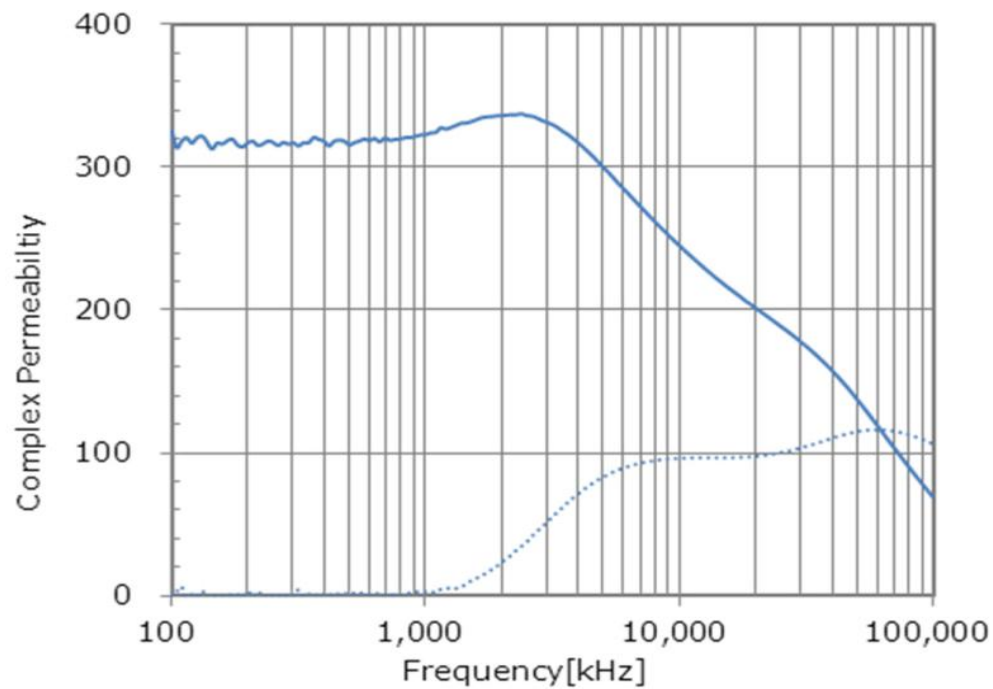
Index	η_0 (%)	μ'_r	$\tan \delta$	$R_1(\Omega)$	$R_2(\Omega)$	M (nH)
6	91.31	171	0.0164	1.018	1.085	650.5
5	90.97	142	0.0108	1.046	1.111	629.6
7	90.81	95	0.0057	1.031	1.085	583.1
4	90.81	100	0.0069	1.039	1.092	589.1
8	90.04	130	0.0312	1.161	1.222	619.8
9	86.93	260	0.1731	1.653	1.721	690.9
1	85.60	31	0.0645	1.422	1.454	445.4
3	84.14	150	0.2	1.988	2.047	638.4
2	83.58	110	0.1818	2.009	2.059	602.8
10	72.94	100	0.5	3.622	3.667	605.2

Index	μ'_r	μ''_r	$\tan \delta$
1	31	2	0.0645
2	110	20	0.1818
3	150	30	0.2
4	100	0.69	0.0069
5	142	1.54	0.0108
6	171	2.81	0.0164
7	95	0.54	0.0057
8	130	4.06	0.0312
9	260	45	0.1731
10	100	50	0.5

Frequency vs Permeability



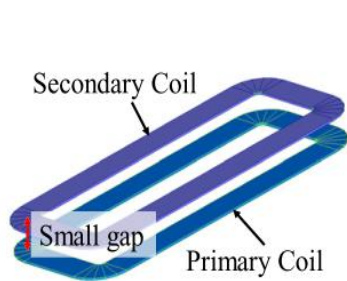
Frequency vs Permeability



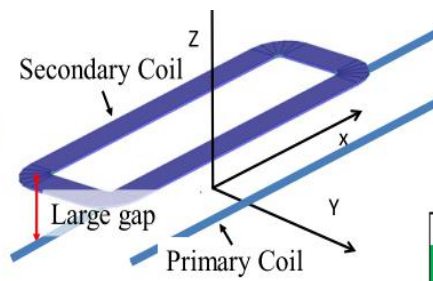
材料几何形状

A Study of Structure of Inductive Power Transfer Coil for Railway Vehicles

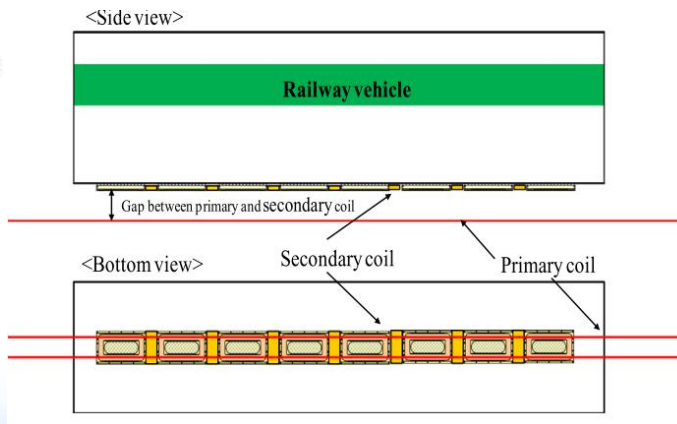
Central Japan Railway Company



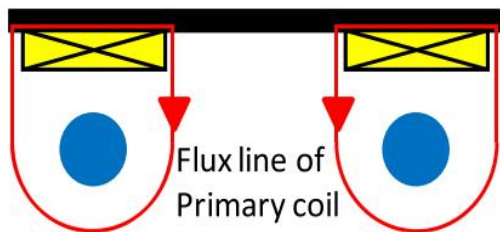
(a) Stationary IPT system



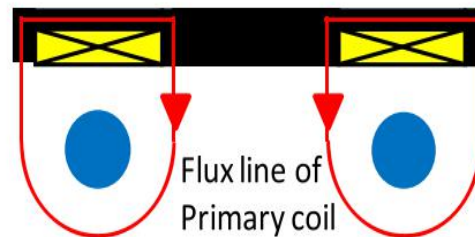
(b) Movable IPT system



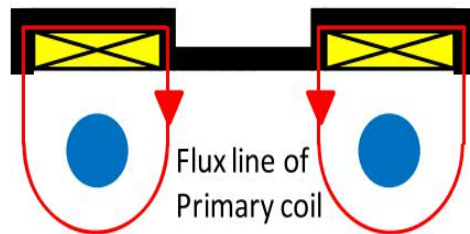
5 kg/kW



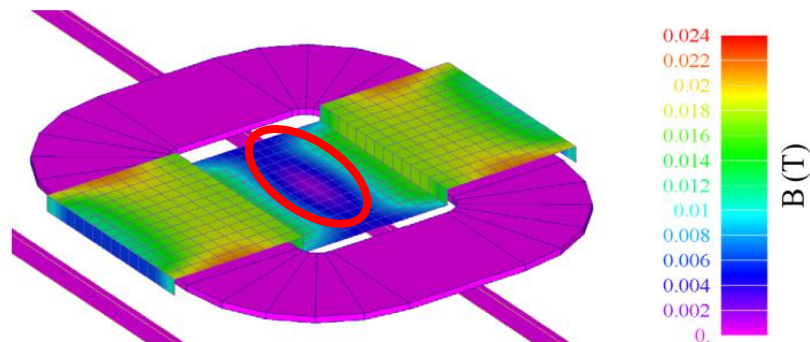
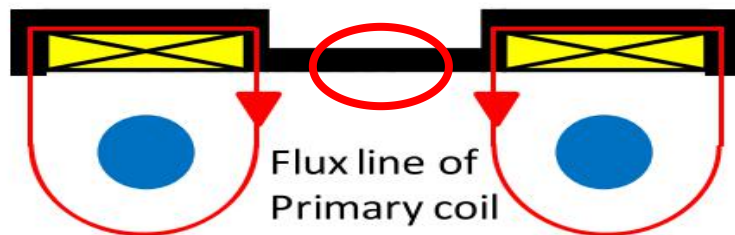
Cross sections of conventional flat-type cores



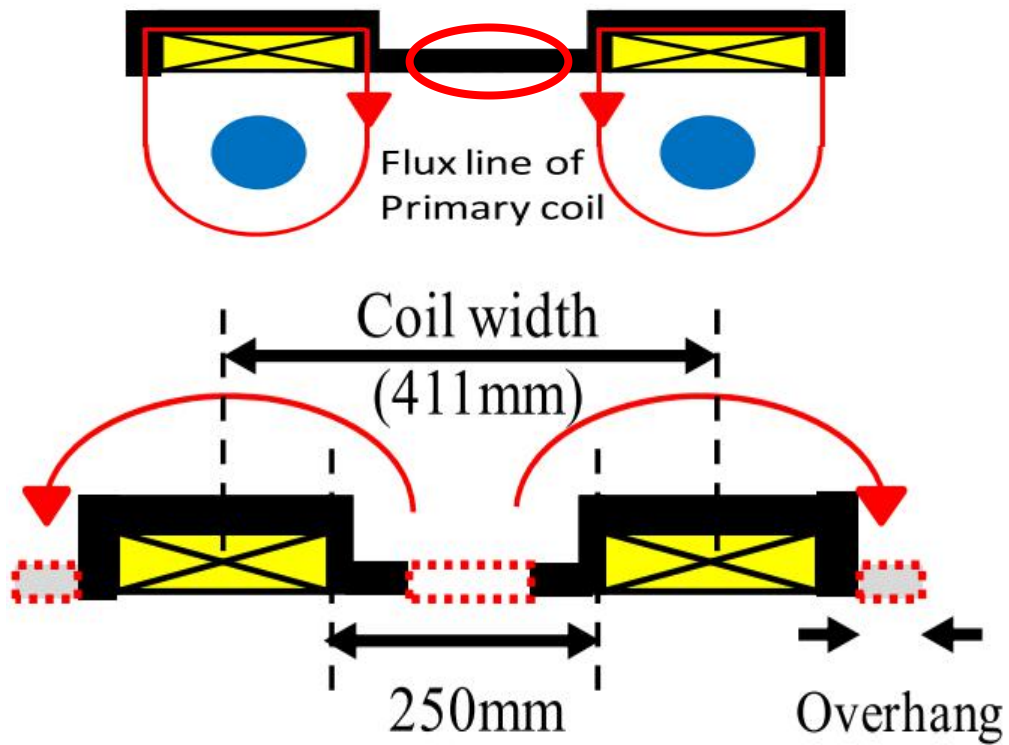
Cross sections of conventional E-type cores



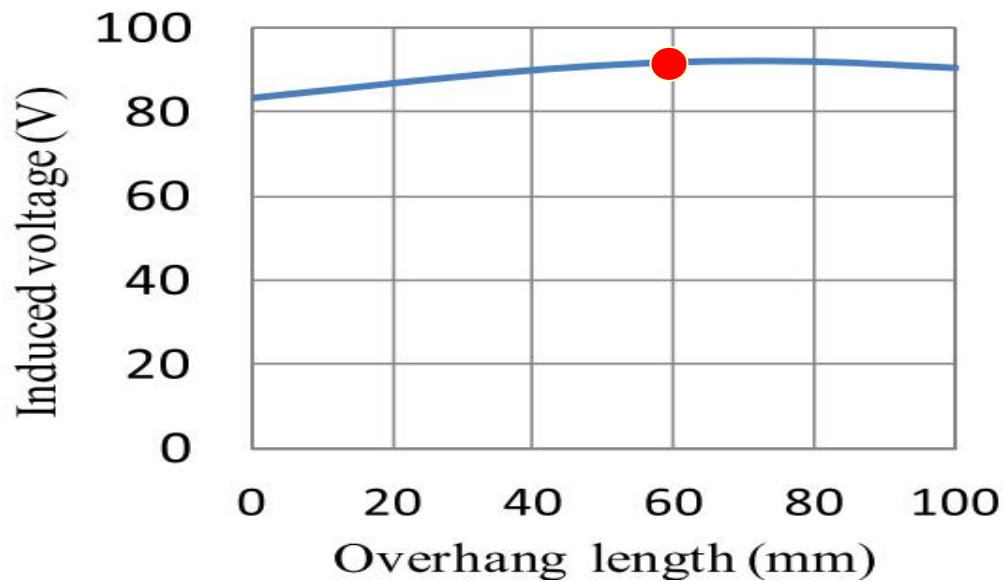
Cross section of new ferrite core (uneven-type core)



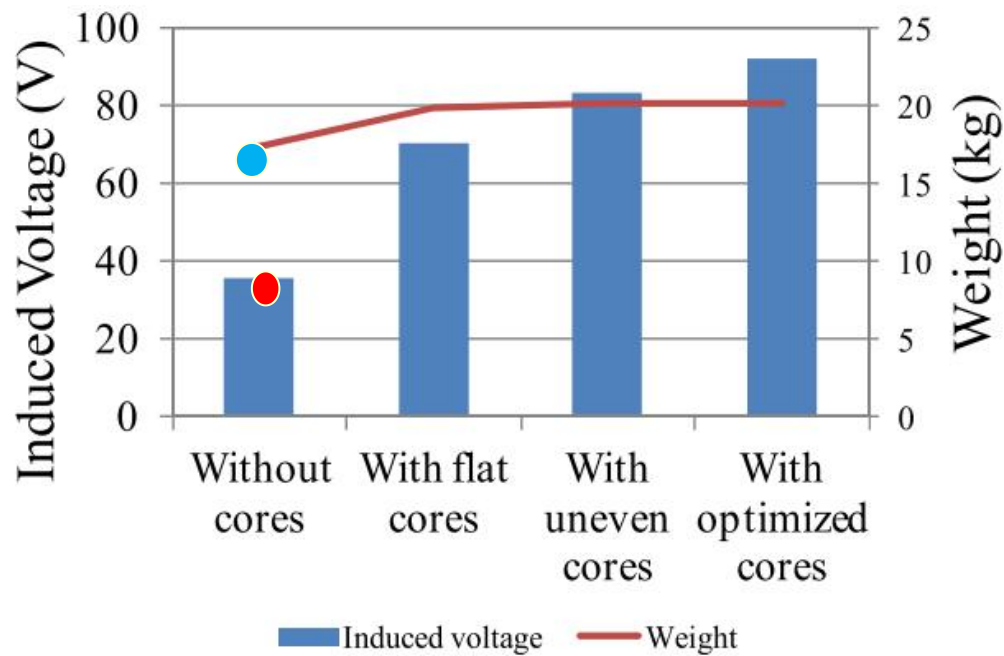
Flux distribution in the uneven-type cores
at the primary current of 20KHz/250 A



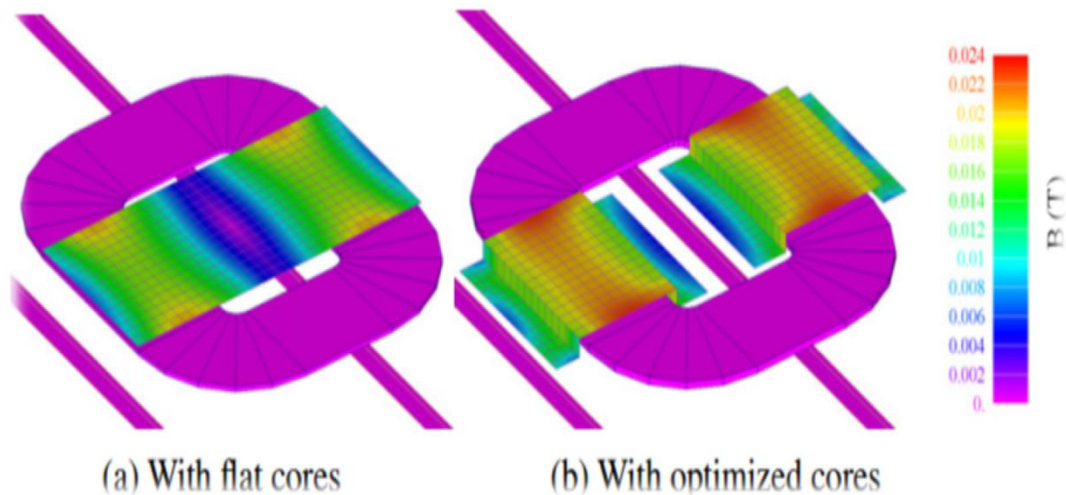
Optimized structure of secondary coil



Induced voltage versus over-hang length



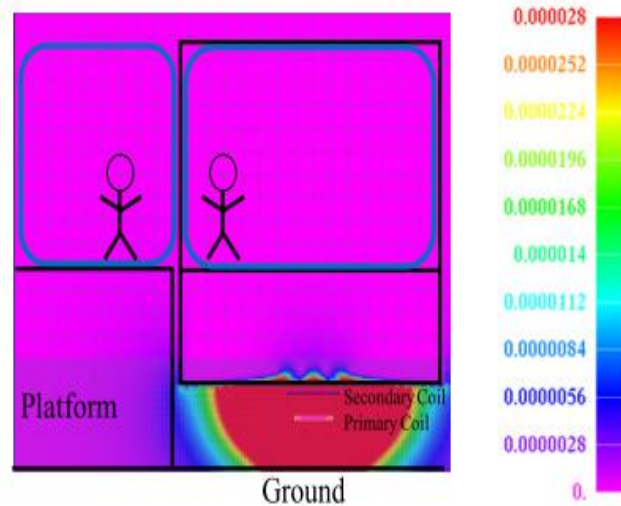
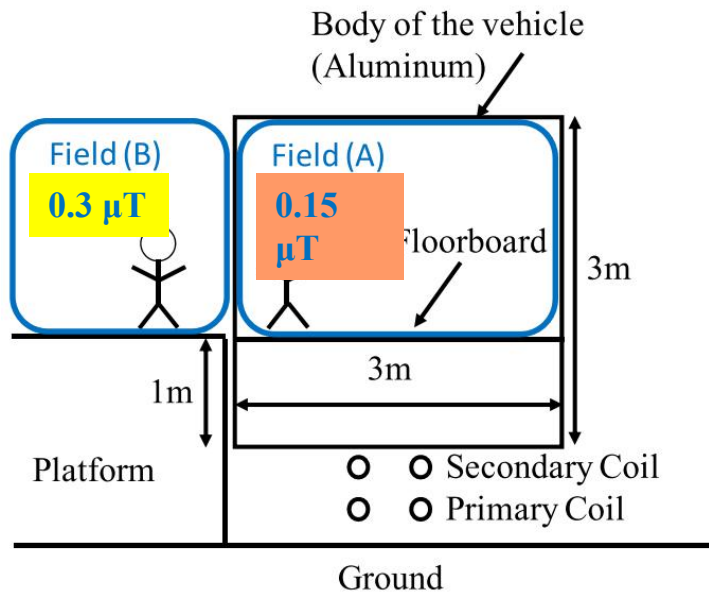
The induced voltage and the weight of the secondary coils with various types of cores

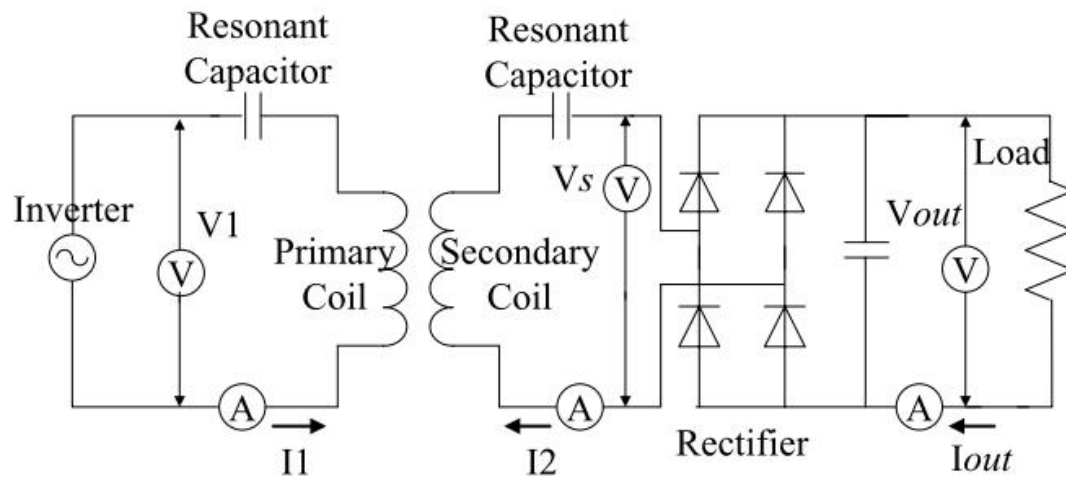


Flux distribution in ferrite cores at the primary current of 250 A

1/180 ICNIRP

1/90 ICNIRP



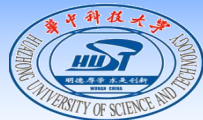


Voltage(V)	260
Current(A)	200
Output(kW)	50
frequency(kHz)	5-50

$$\eta = \frac{P_{out}}{P_{in} + P_l} = \frac{I_{out} V_{out}}{V_1 I_1 \cos \theta + 2I_1^2 R_1}$$

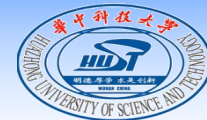
85%

Primary coil (3 turn)	Width	0.4 m
	Length	3 m
	L ₁ (μH)	31.0
	R ₁ (mΩ)	25.0
Secondary coil (15 turn)	Width	0.4 m
	Length	0.5 m
	L ₂ (μH)	225.7
	R ₂ (mΩ)	39.3
Resonant capacitor	C ₁ (μF)	2.4
	C ₂ (nF)	283.0



电动汽车WPT系统

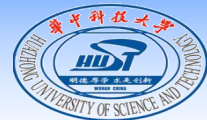
- 指南、标准
- 国内外的WPT电动汽车
- 电动汽车WPT中的铁氧体磁性材料
- 问题及思考



指南、标准

国际标准情况

2016年5月31日，美国汽车工程师协会SAE 发布无线充电指南：
TIR J2954规定通用频带85KHz（81.39-90kHz）。四个等级的插电
以及全电动汽车无线能量传输水平(WPT1, WPT2, WPT3, and
WPT4) 3.7, 7.7, 11.1, 22 kVA

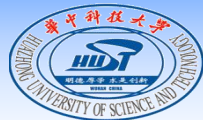


GB/T XXXX 《电动汽车无线充电系统 通用要求》编制说明

- ◆ 2015年7月，国家标准委下达“《电动汽车无线充电系统 通用要求》等14项国家标准制修订计划”，《电动汽车无线充电系统通用要求》正式立项，计划编号20150675-T-339。
- ◆ 2015年12月16日，电动汽车无线充电标准化联合工作组第一次工作会议暨项目组启动会在成都新华国际酒店举行。
- ◆ 2016年7月28日，《电动汽车无线充电系统 通用要求》国家标准项目组第二次会议在银川召开。
- ◆ 2016年10月25日，《电动汽车无线充电系统 通用要求》国家标准项目组第三次会议在重庆召开。最终形成国家标准的征求意见稿。

中电联就《电动汽车无线充电系统 特殊要求》等三项国标征求意见

2017年8月29日，中电联就《电动汽车无线充电系统 特殊要求》、《电动汽车和无线充电系统设备之间的通信协议》和《电动汽车无线充电系统电磁环境限值与测试方法》三项国标征求意见。



国内外的WPT电动汽车

多国在公交线路上 探索大功率无线充电

- ◆ **韩国：**韩国在2013年8月推出了一种新型的 公交车，这种公交车已经在韩国南部的龟尾市投入使用，长达12公里的公交路线也是世界上第一条可连续充电的公交车道。感应设备距离地面大约为 17厘米。
- ◆ **德国：**德国地区性巴士公司RNV在2013年测试使用无线感应充电技术的巴士。测试运营的范围为曼海姆市区的63号线。
- ◆ **英国：**2014年1月份，英国在米尔顿凯恩斯 试运营无线充电的电动公交大巴。整个线路的长度为15英里，巴士大约会消耗三分之二的能量，回来的巴士只需要在充电点停10分钟，电力又可以被加满。公交车会在起点站和终点站进行无线充电，所有的8辆巴士只需要2个无线充电点对其服务。

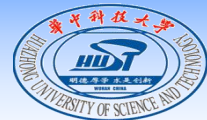


2011年东京车展上，日本丰田与三菱汽车均展出了具有无线充电功能的电动汽车，采用“磁共振方式”进行非接触充电。输出功率为3KW，供电装置与接收电装置间的传输效率为90%以上，实现这一效率的送受电装置的位置误差容许度为垂直方向20cm，水平方向20cm。

南宁新增无线充电公交车 节假日专线将服务邕城

2017-09-21





公交车无线充电装置总功率为60千瓦，每分钟可充6度电。有线充电桩充电每次需五六个小时，无线充电装置投入运行后，理论上充4分钟就可跑完单程。现在一条纯电动车公交线投入成本约为6800万元（含充电站、土地、车辆等），无线充电技术可使成本降至3600万元。（襄阳）

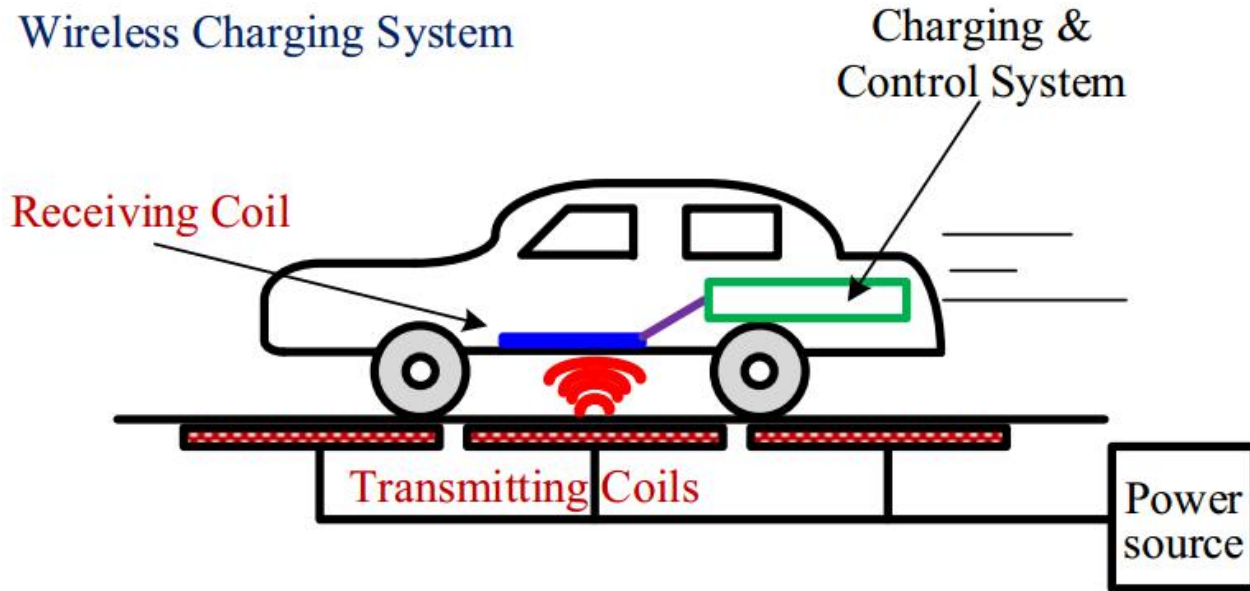
每两分钟就可以充1度电，在等待乘客的间隙，耗时不到8分钟所充电量就可以跑一圈。无线充电公交有三大优点，一是充电快，2分钟1度电，每公里耗电0.4—0.8度；二是方便，无人值守，自己完成；三是安全，无线充电不惧任何恶劣天气影响。（成都）

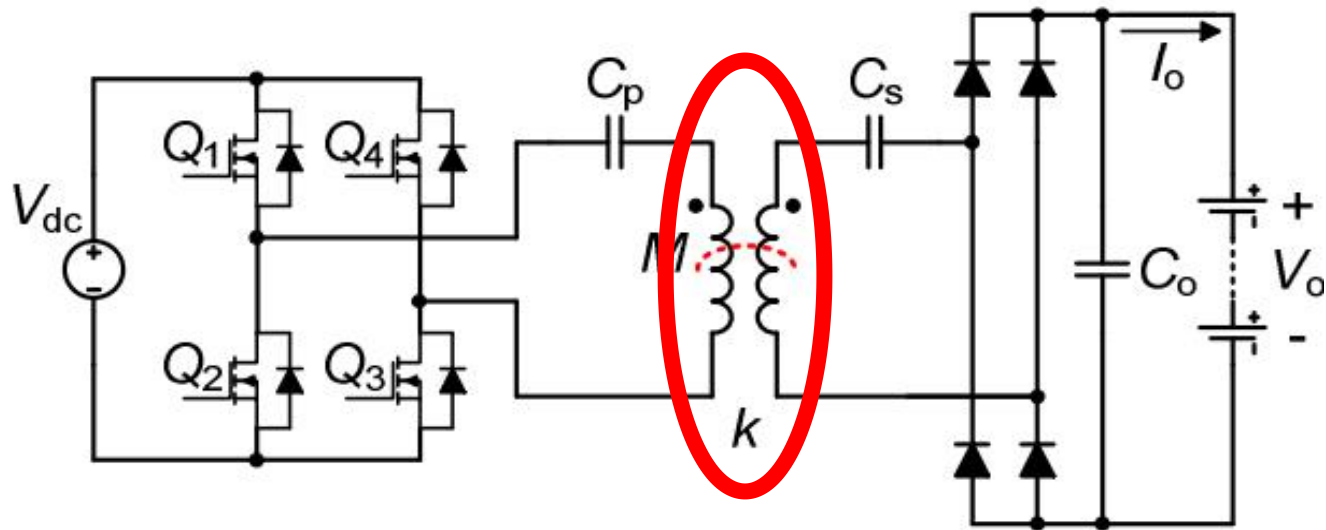
采用国内首创的磁耦合谐振技术研的30kW的无线供电产品，传输距离最大可达60CM(±5)，而且具有相当程度上的水平和垂直自由度，主要应用在大巴车和城市公交上。（[北汽EV200](#)）

在停车位地下埋一个发射线圈，在车底盘安装一个接收线圈。在无线充电过程中，一般小型车需要功率5kw-7kw，大巴车需要30kw-60kw，无线充电的整体效率可达到90%。（中兴通讯）

具备无线充电功能的家用汽车，车上配备的无线充电设备售价不会超过原有价格一万块钱，停车位地下的设备与改造投资每个不超过两万。（中兴通讯）

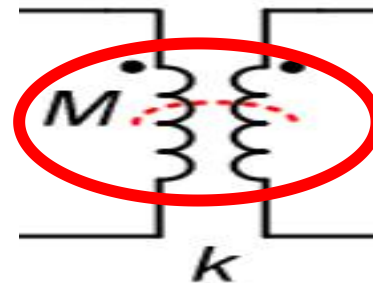
电动汽车WPT中的铁氧体磁性材料





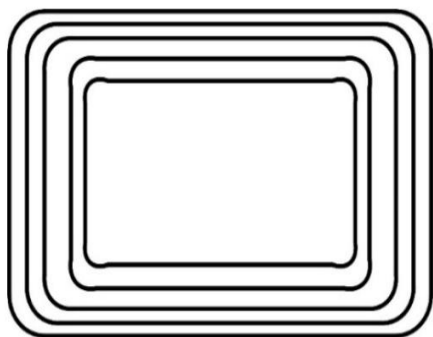
Overview of Coil Designs for Wireless Charging of Electric Vehicle

2017 IEEE

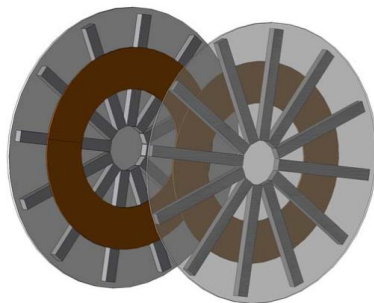


电动汽车无线充电的磁耦合结构综述

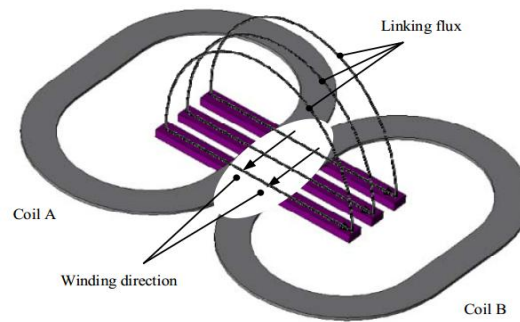
2017年第4期 电气技术



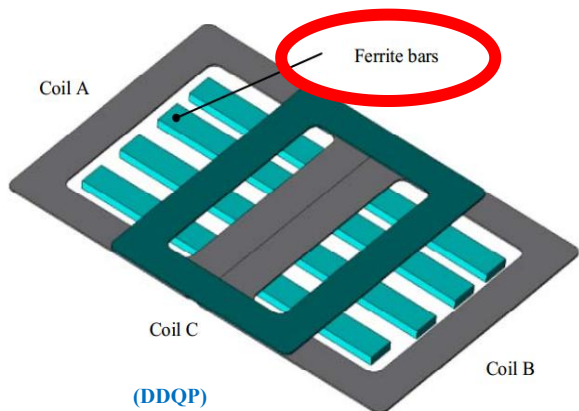
(CRP)



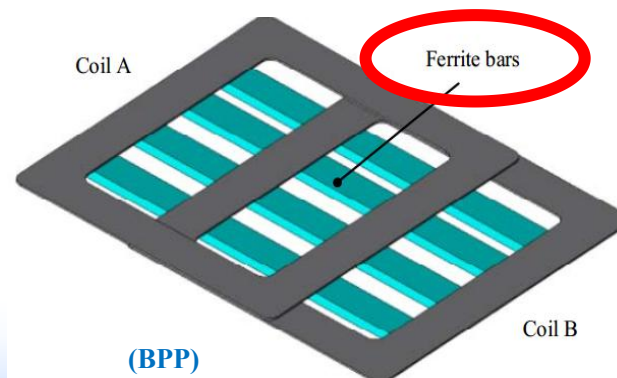
(CP)



(DDP)



(DDQP)



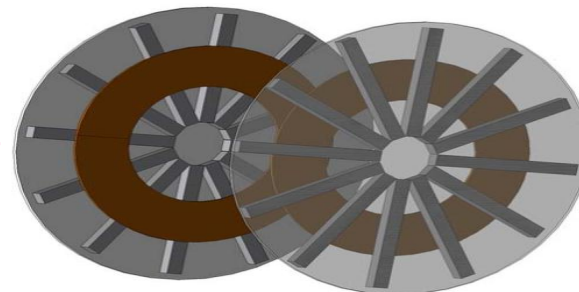
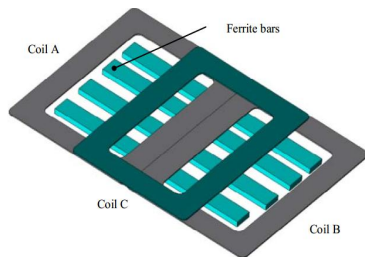
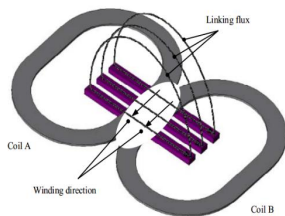
(BPP)

	CRP	CP	HP	DDP	DDQP	BPP
Transferrable power	Medium	Medium	Low	High	High	High
Pad design size	Medium	Medium	Large	Small	Small	Small
Pad weight	Low	Low	High	Low	Medium	Medium
System material cost	Low	Low	High	Medium	High	Medium
Transmission distance	Low	Low	Medium	Medium	High	High
Charging zone	Small	Small	Large	Medium	Large	Large

充电区域

发射线圈 —— 接受线圈

发射线圈 —— 接收线圈



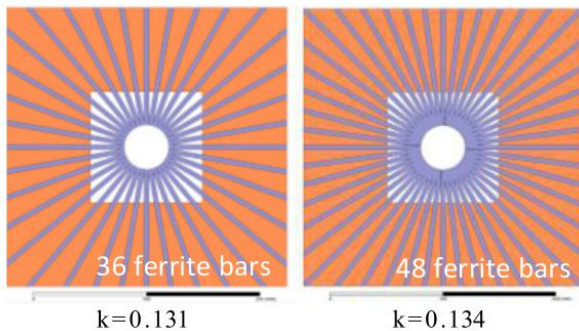
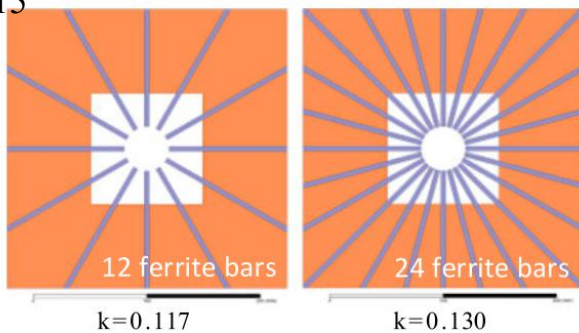
DDP —— DDQP

CP —— CP



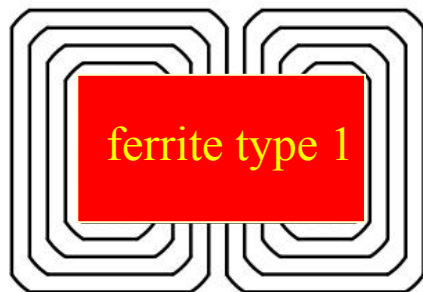
Loosely Coupled Transformer Structure and Interoperability Study for EV Wireless Charging Systems

IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 30, NO. 11, NOVEMBER 2015



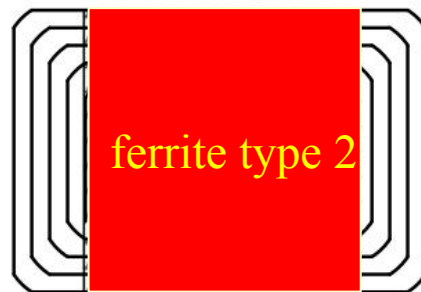
铁氧体条数	耦合系数
0	0.079
12	0.117
24	0.130
36	0.131
48	0.134

利用磁片的k值为**0.136**



ferrite type 1

K=0.184



ferrite type 2

K=0.164



ferrite type 3

K=0.153



ferrite type 4

K=0.132

2016 Eleventh International Conference on Ecological Vehicles and Renewable Energies

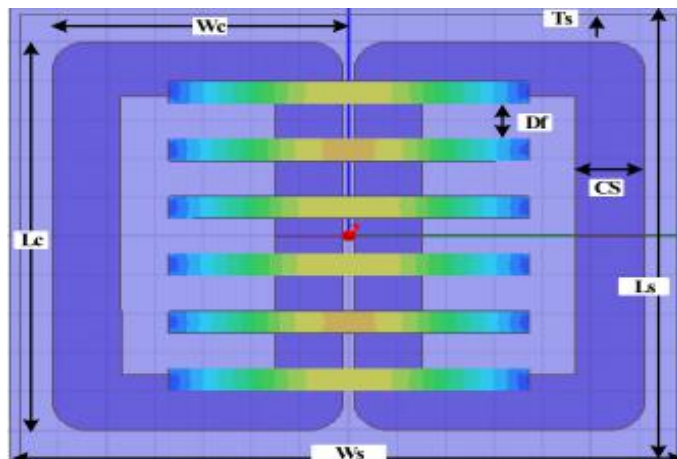
Comparison of Coil Topologies for Inductive Power Transfer under the Influence of Ferrite and Aluminum

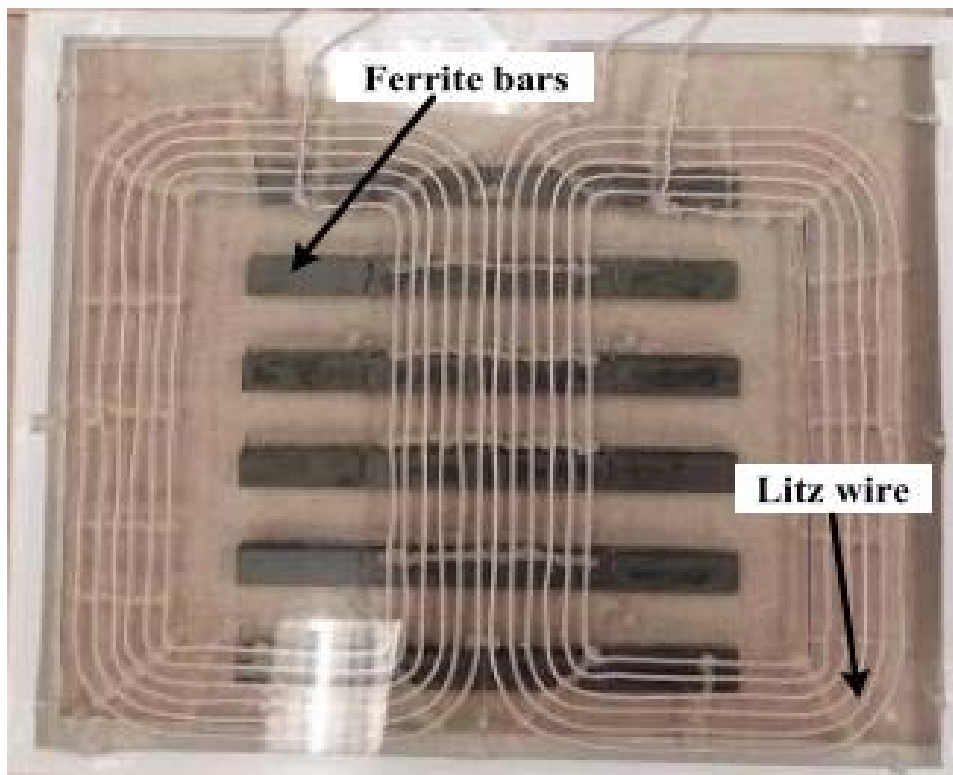
Coil diameter	550 mm
Cross section of coil	50 mm ²
Number of turns	5
Distance between windings	20 mm
Air gap	150 mm
Lateral misalignment	0 mm
Ferrite	Ø 650 mm x 5 mm
Aluminum	Ø 700 mm x 5 mm
Aluminum vehicle	Ø 1400 mm x 2 mm

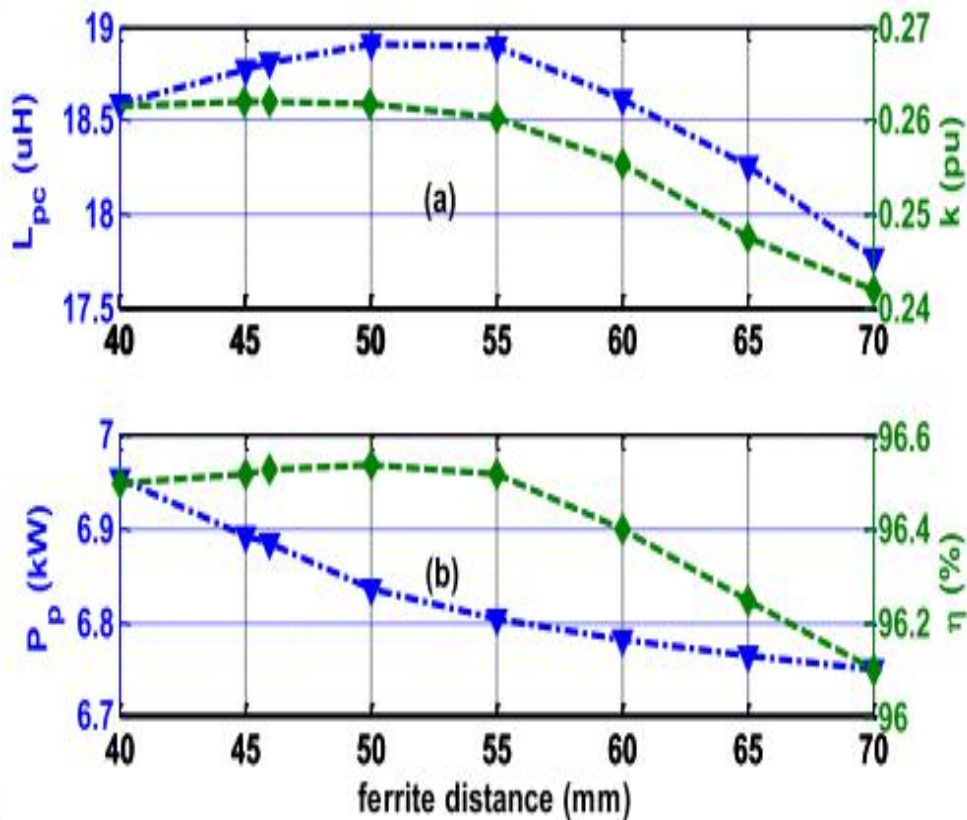
	Air core coil	With ferrite	With aluminum	With ferrite & aluminum
Self-inductance [uH]	13.59	25.39	2.54	22.91
Mutual inductance [uH]	3.58	9.94	0.06	7.55
Coupling factor	0.26	0.39	0.02	0.33
Magnetic flux density at vehicle body [uT]	10.74	12.04	0.09	1.74

Magnetic Design Considerations of Bidirectional Inductive Wireless Power Transfer System for EV Applications

IEEE TRANSACTIONS ON MAGNETICS, VOL. 53, NO. 6, JUNE 2017

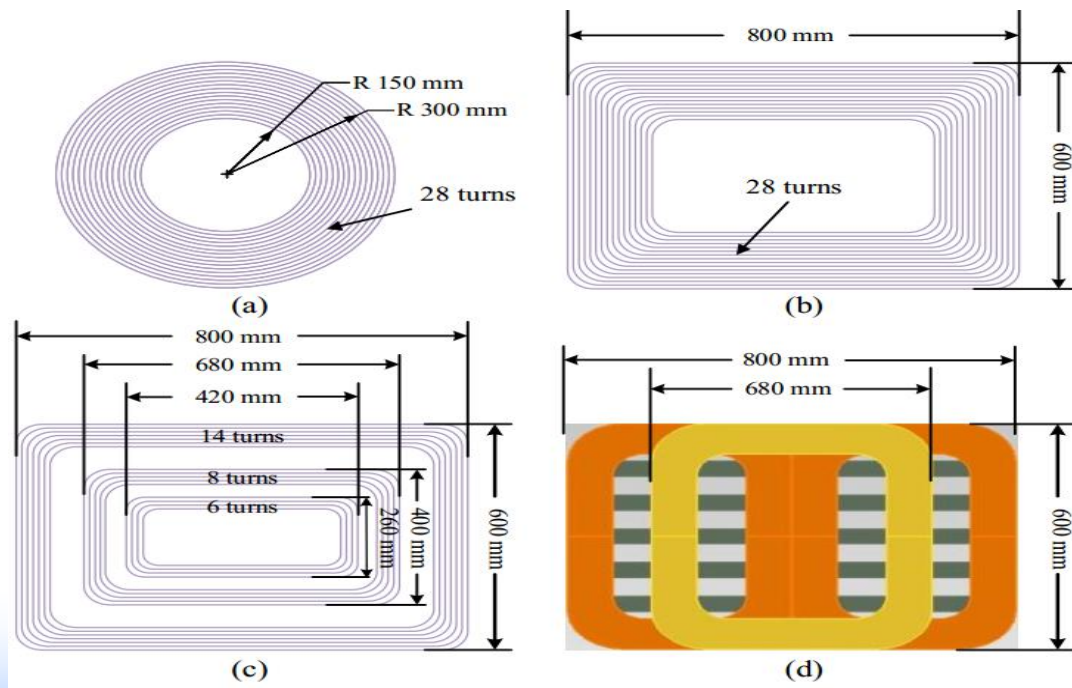


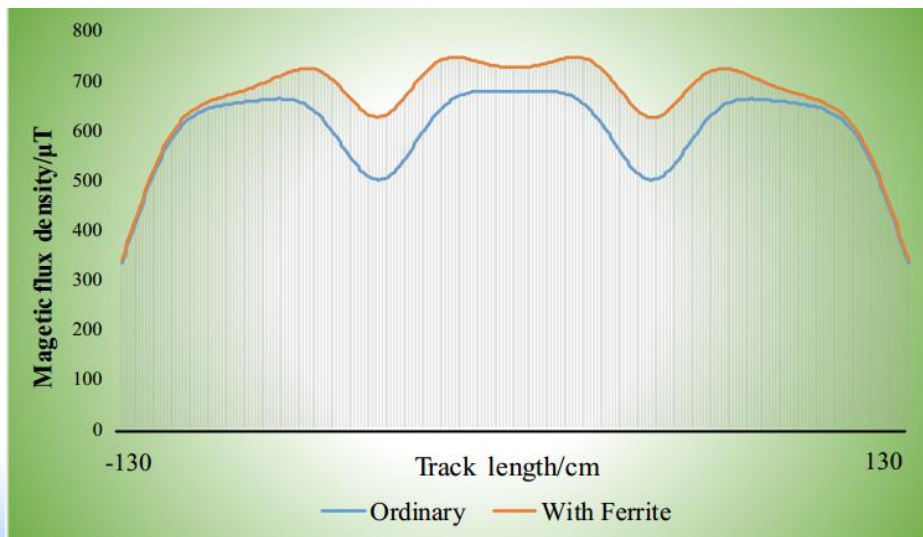
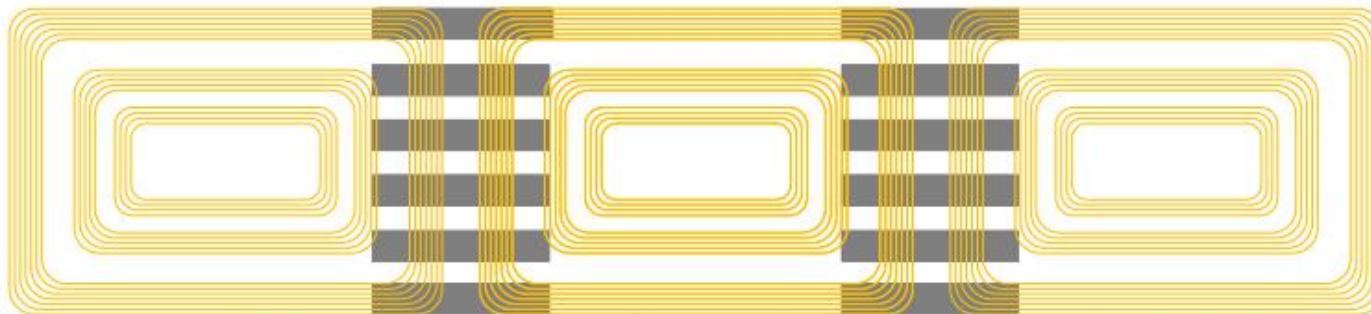


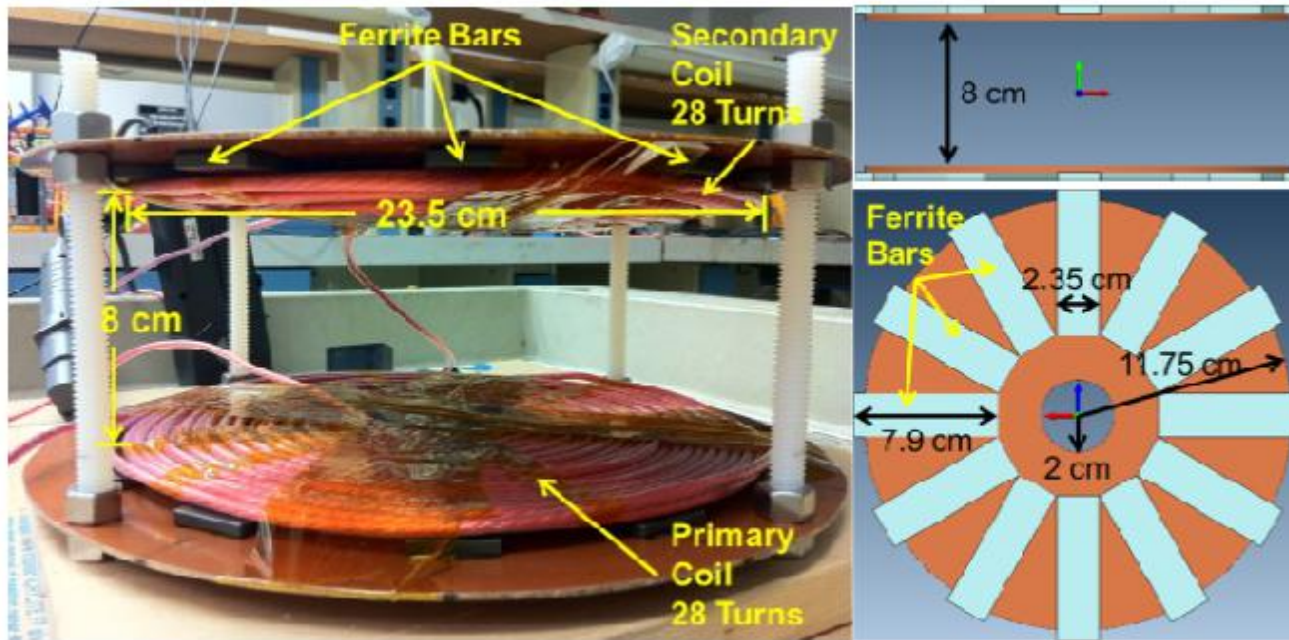


Comparative Analysis and Optimization of Dynamic Charging Coils for Roadway-Powered Electric Vehicles

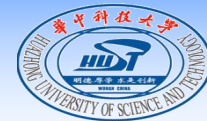
IEEE International Magnetics Conference, April 24-28, 2017.



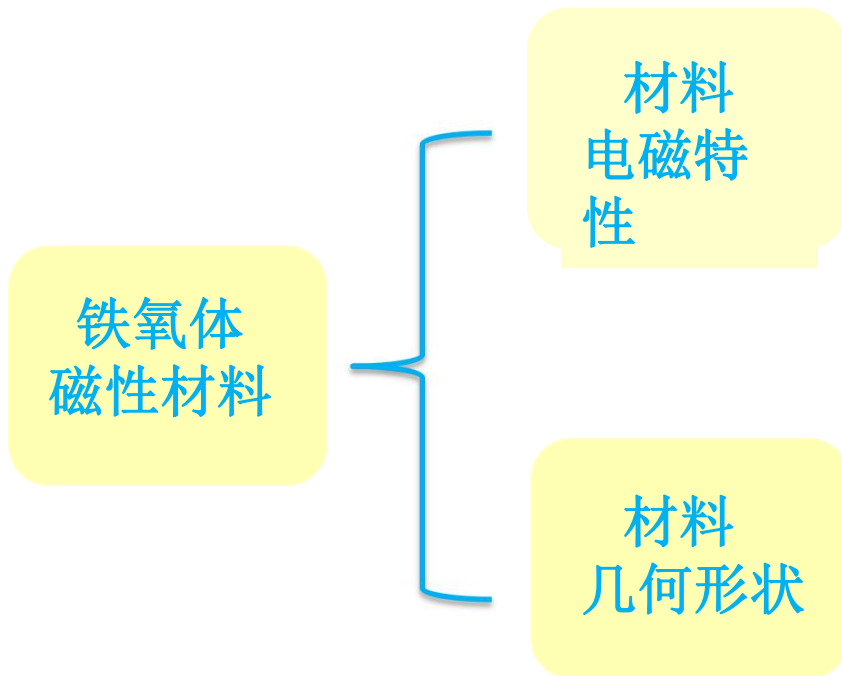
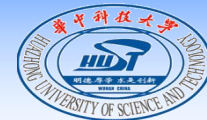


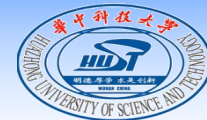


问题及思考



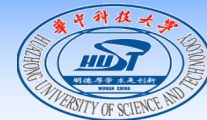
WPT系统中的铁氧体材料的发展





➤ 材料电磁参数

- 适应工作频率变化
- 适应系统特殊要求
- 适应工作环境要求



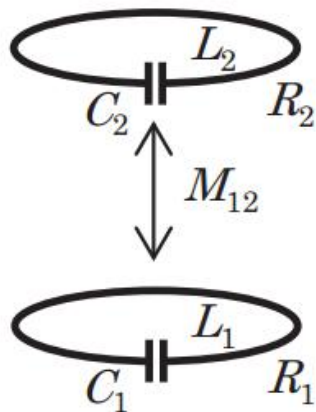
➤ 材料几何形状

- 增强系统效率
- 符合ICNIRP规则
- 新型工艺

Center-Constricted Magnetic Core-Coil Structures for Resonant Wireless Power Transfer

Fujitsu Laboratories Ltd.,

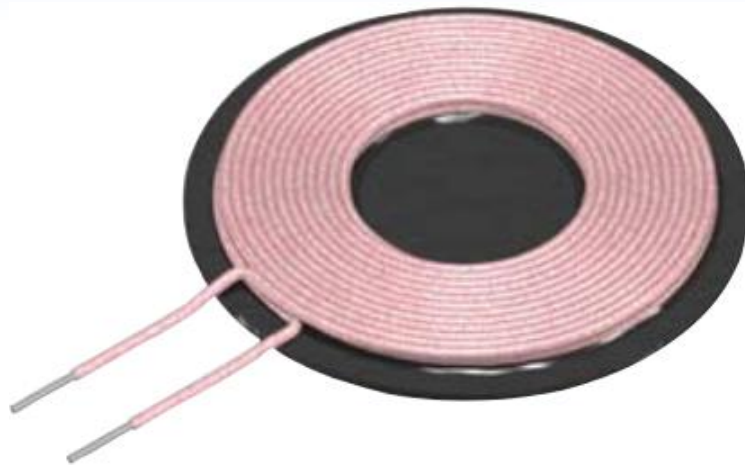
线圈之间的能量传输效率由二线圈之间的耦合系数（ k ）和线圈的品质因数（ Q ）的乘积 kQ 确定。



kQ

优 值

耦 品
合 质
系 因
数 数

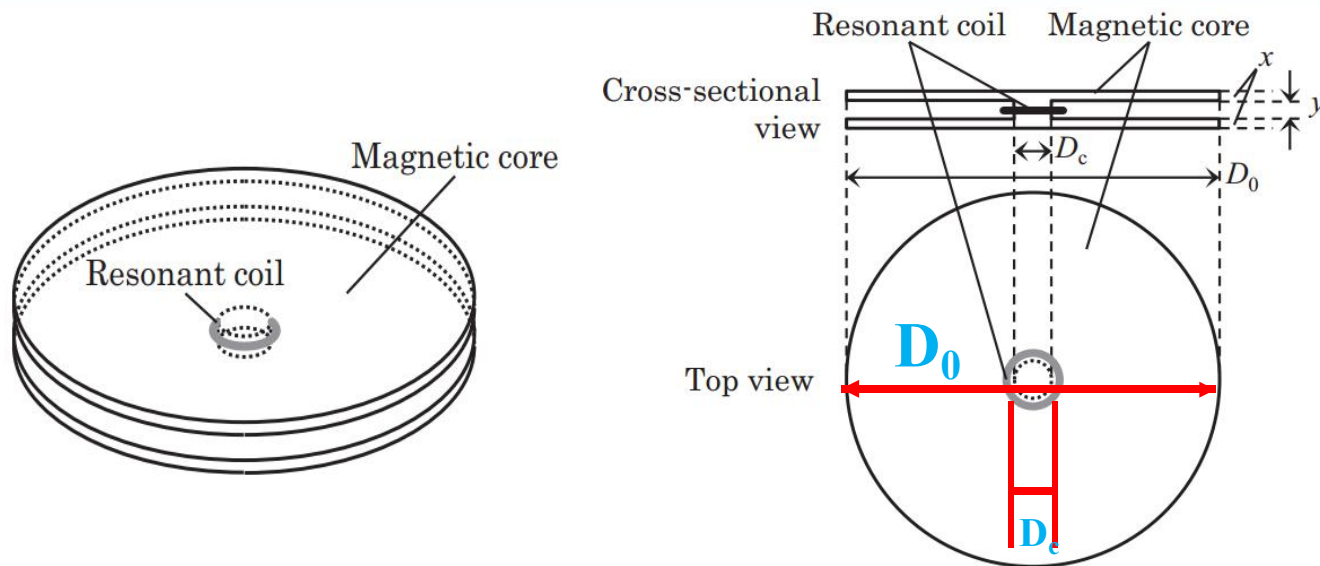


$$L = L_0 / N_D$$

线圈电感
量

空心线圈电感
量

退磁因
子

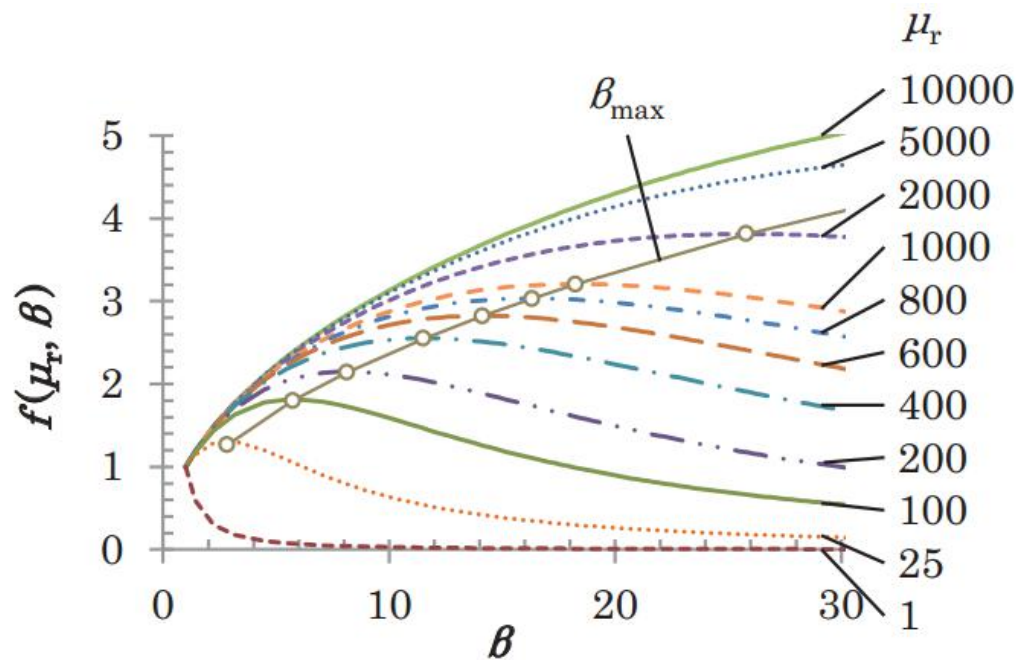


$$\beta = D_0/D_c$$

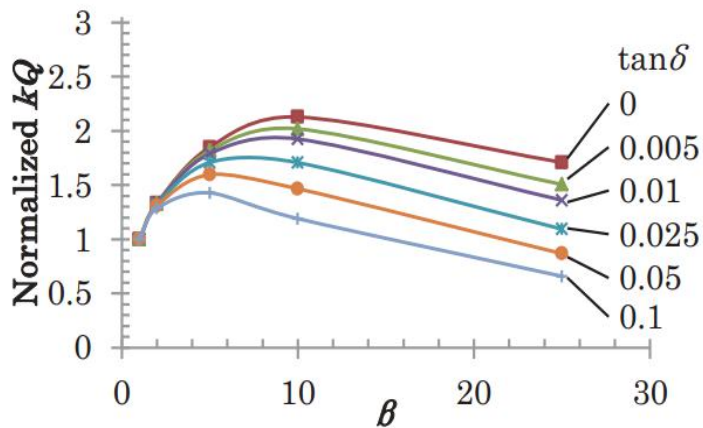
$$kQ = \mu_r \beta^{1/2} / (\mu_r + \beta^2 - 1) k_0 Q_0$$

增强因子 $f(\mu_r, \beta) = \mu_r \beta^{1/2} / (\mu_r + \beta^2 - 1)$

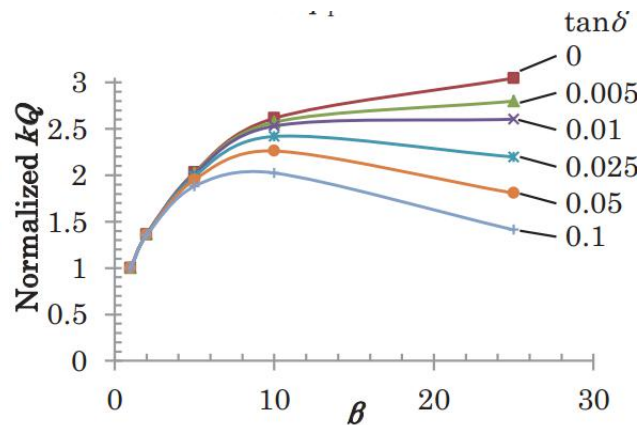
$\mu_r = 1000$ $\beta = 10 \longrightarrow kQ = 2.88 k_0 Q_0$



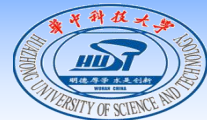
$$\tan \delta = \frac{\mu''}{\mu'} = \frac{\mu_r''}{\mu_r'}$$



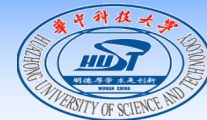
(a) $\mu_r = 1000$



(b) $\mu_r = 5000$



- 提出了用于共振无线功率传输的对置扁平线圈的中心收缩磁芯线圈结构。通过电磁场仿真我们导出了线圈系统的优值 KQ 。
- 研究表明，该结构的应用可以提高 KQ 不增加磁芯的厚度。
- 从磁学的角度研究将有助于提高这种系统的性能。



我们的工作

江西耀润磁电科技有限公司根据WPT系统的要求，进行了应用于WPT系统的铁氧体磁性材料的开发。目前已经开发了系列WPT系统应用的铁氧体磁性材料。

★材料主要电磁参数

起始磁导率	饱和磁通密度 (mT) H=1194A/m		功率损耗(mw/cm ³) (200KHz/100mT)		密度 (g/cm ³)	居里温度 (°C)
	25°C	100°C	25°C	100°C		
2300	500	380	300	200	4.8	≥200

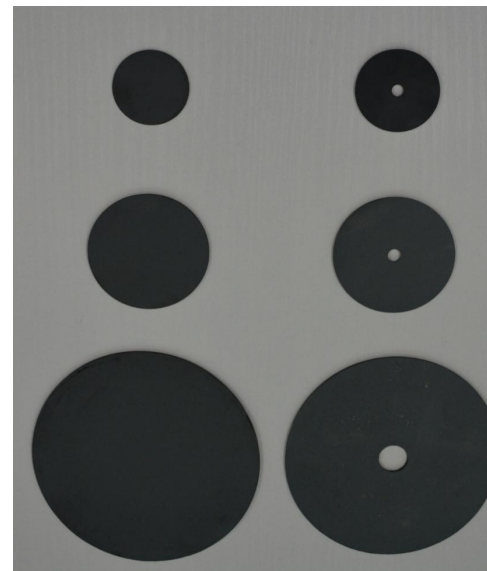
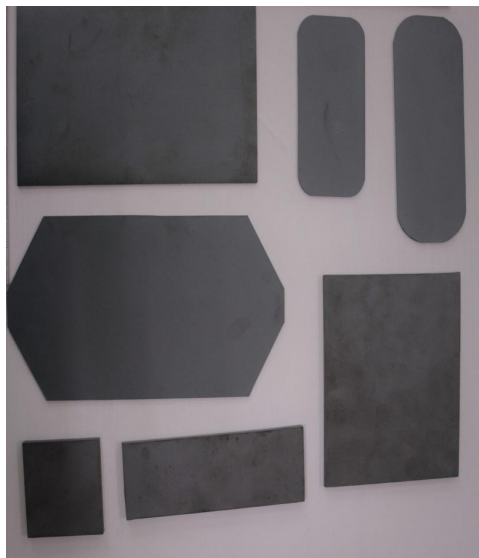
材料尺寸

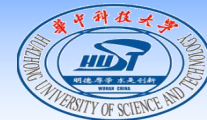
268*50*4	268*17*3	268*126*3
266*52*3	248*22*3	206*30*3
123*52*0.8	120*40*5	113*98*4
100*100*3	70*70*0.8	55*55*1
Φ94*Φ12*1	Φ60*Φ12*4	Φ60*3
Φ50*1.0	Φ50*0.6	Φ7*0.5

★材料照片



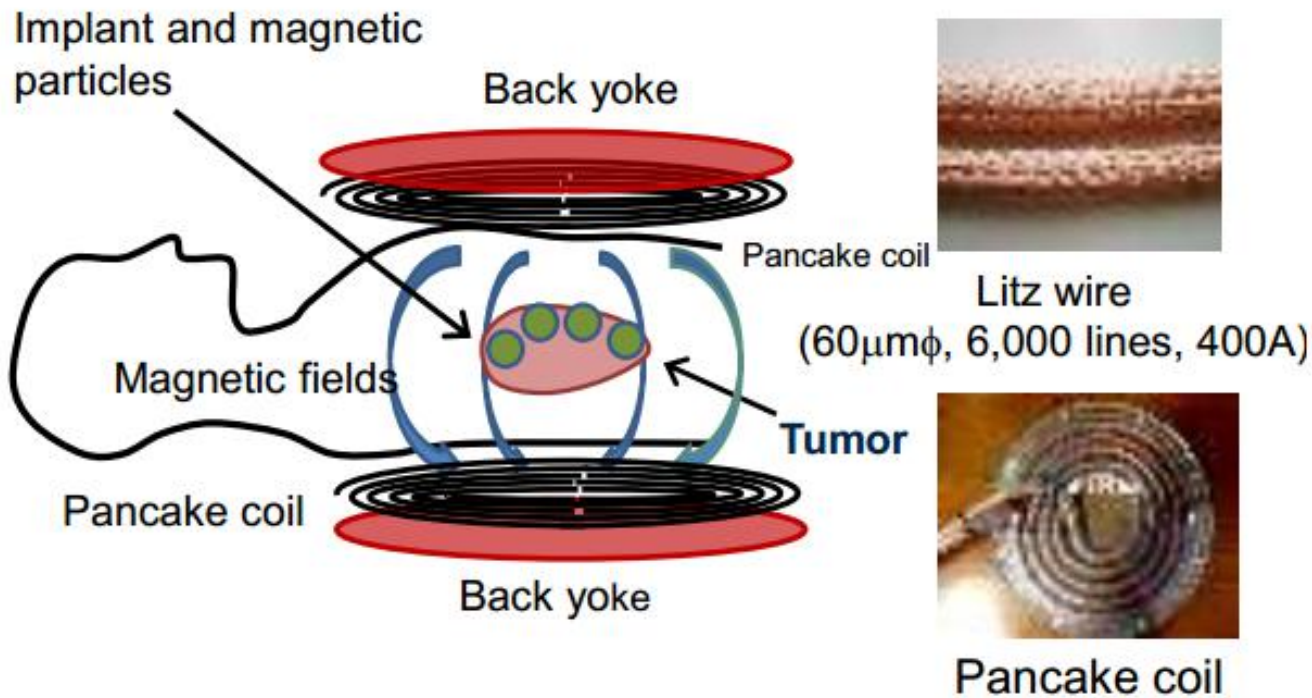
★材料照片

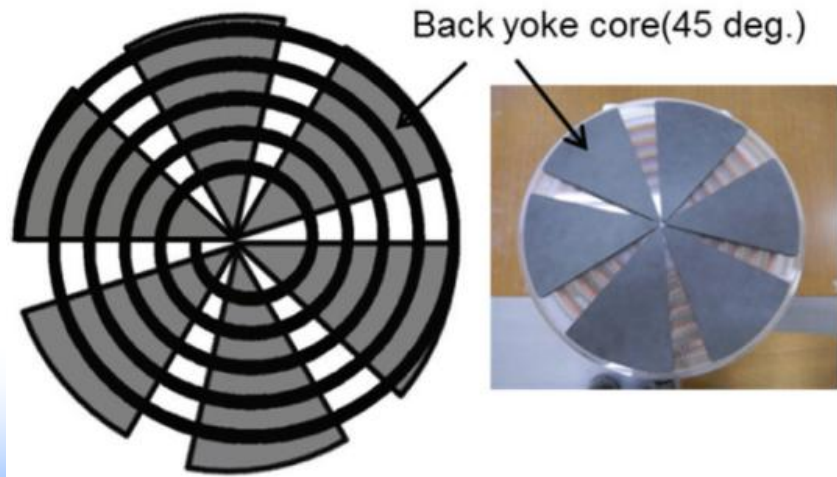
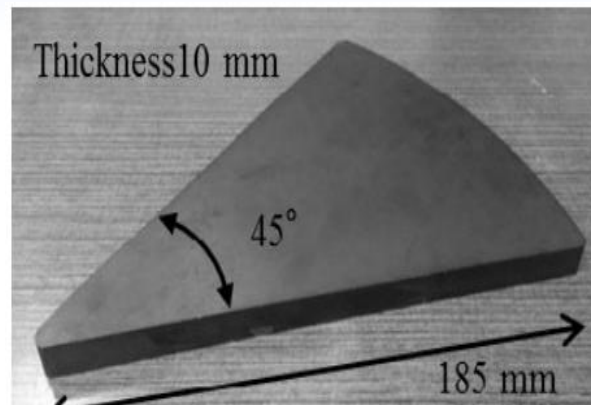
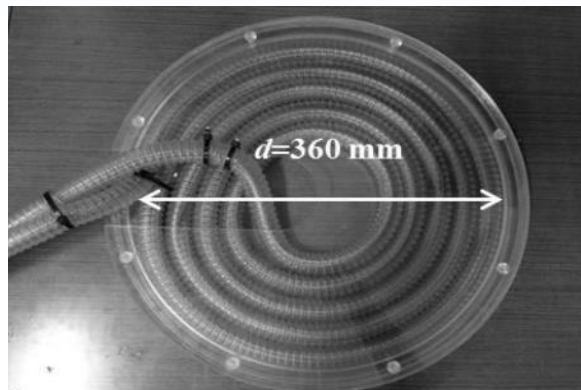


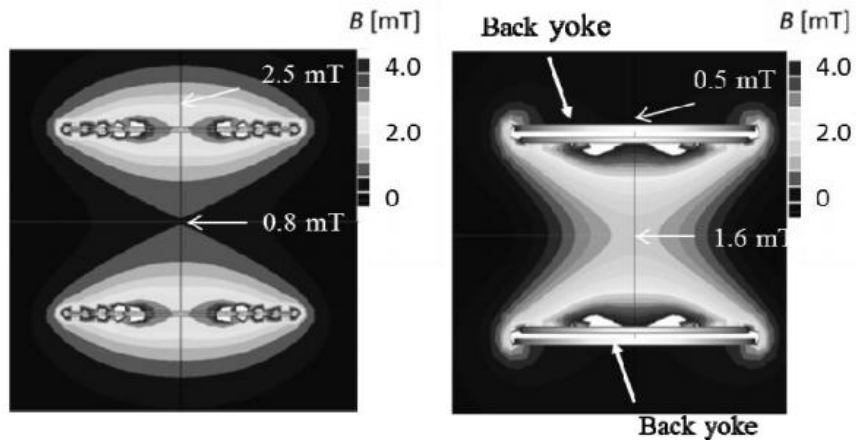
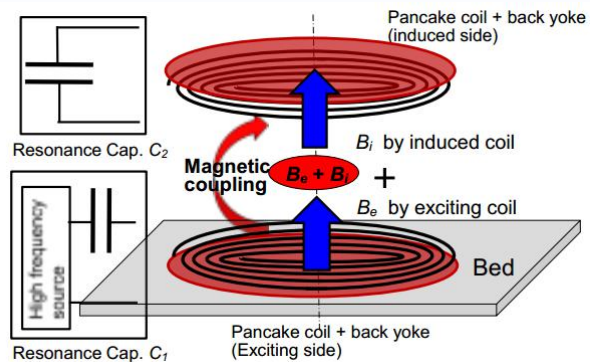


谢谢!

敬请各位指正

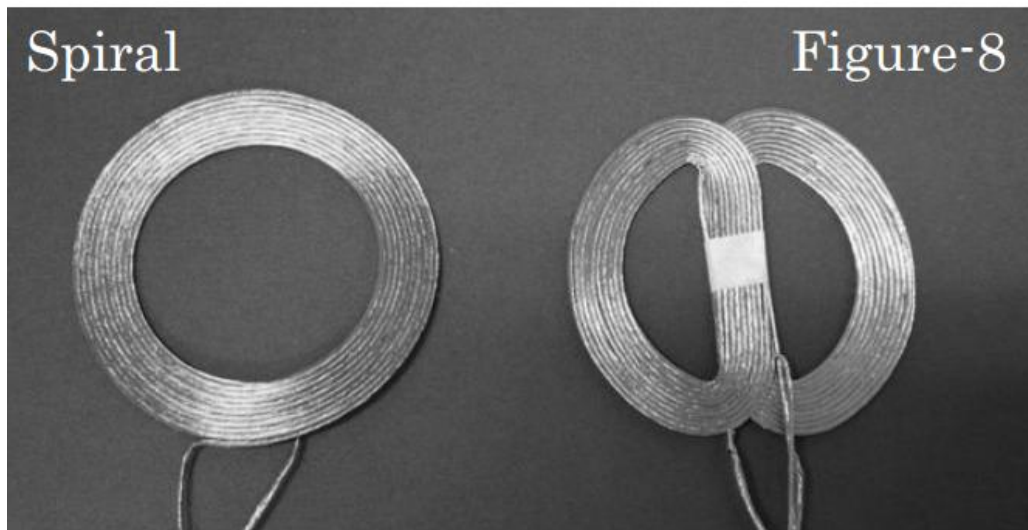






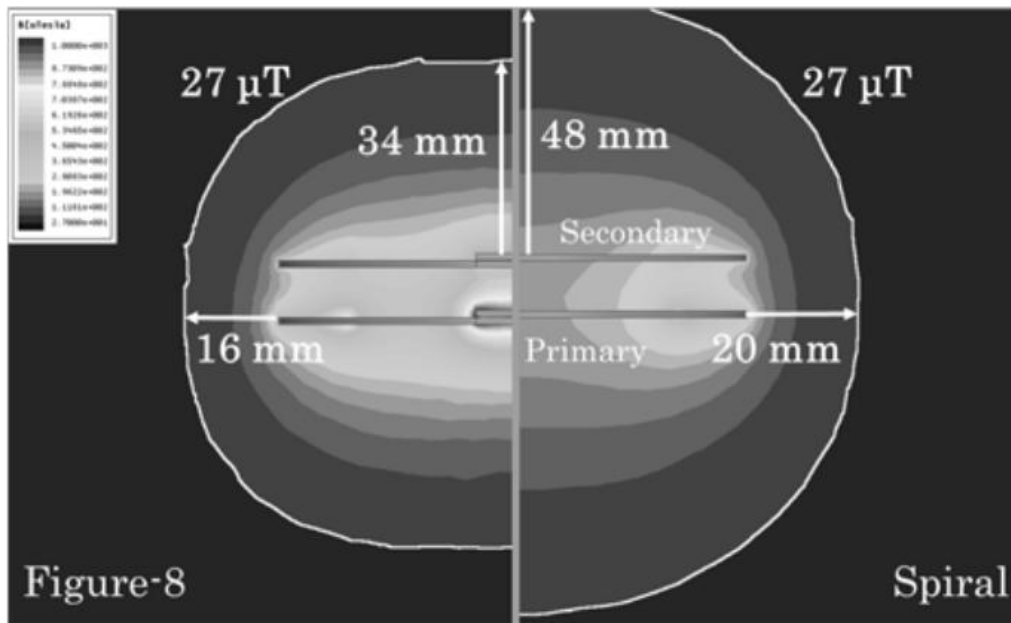
(a) Without back yoke. (b) With back yoke.

无线功率传输中漏磁场减小与线圈形状的关系



日本东北大学、Hikaridenshi

	Figure-8 coil	Spiral coil
Outer diameter		
[mm]	80	80
Turns	10	10
L [μH]	15	10.5
r [$\text{m}\Omega$]	147	95
Q	127	139



Efficiency of wireless power transmission (with ferrite plate)

	Figure-8 coil	Spiral coil
I_1 [A]	0.35	0.28
I_2 [A]	0.5	0.5
P_{in} [W]	2.57	2.53
P_{out} [W]	2.5	2.5
Efficiency [%]	97.1	98.6