Seal Effects on Wireless Power Transfer Systems via Magnetic Resonance Coupling

Xinzhi Shi[1,2], Chang Qi[2], Meiling Qu[2], Zhenhua Shi[2], and Houxiang Xu[2]
[1] Research Institute of Wuhan University in Shenzhen, Shenzhen, China
[2] Institute of Microelectronics and Information Technology, Wuhan Univeristy, Wuhan, China

***Abstract* - In this work, a comprehensive study on seal effects on WPT systems via magnetic resonance coupling is conducted by virtue of full-wave electromagnetic solutions. Five sealing materials, Cu, ABS, earth, glass and sea-water, are discussed. It is shown that the resonant frequencies of the WPT systems sealed by the five materials change a little or unchanged. ABS and glass have little seal effects on the efficiencies of WPT systems. The efficiencies of WPT systems sealed by Cu material, earth material and sea-water material will decrease dramatically, and the WPT systems sealed by Cu can hardly transfer energy wirelessly. Therefore the WPT systems can be protected by sealed with ABS or glass materials, and should avoid to be sealed with Cu material. The results are also verified by experiments.**

***Index Terms* —Wireless power transfer, magnetic resonance coupling, four coil resonators, seal effects.**

I. INTRODUCTION

The recent breakthrough in the WPT technology based on magnetic resonance coupling in high-frequency (HF) bands has opened up a revolutionary paradigm for mid-range power transfer [1]. The WPT via magnetic resonance coupling has also been extended into various applications, such as machinery rat, underwater robots, electric vehicles, LED TV, medical implants, wireless sensor networks, etc.

Therefore wireless power transfer systems via magnetic resonance coupling have broad range of applications. But sometimes the coils are sealed by some materials or some media, such as earth, glass, sea-water and etc. The mechanism of WPT via magnetic resonance coupling is different from other WPT technology[1], and the seal effects should be also different. So the seal effects on WPT systems via magnetic resonance coupling should be studied. The impacts of some materials on WPT systems, such as human tissue, reinforced cement, and water were studied in references [2-5]. But the seal effects on WPT systems via magnetic resonance coupling are not studied.

In this work, seal effects on the four-coil WPT system via magnetic resonance coupling are studied in-depth. In particular, the dependences of the power transfer efficiency and the resonant frequency on the sealing material, such as Cu, ABS (Acrylonitrile Butadiene Styrene), earth, glass and sea-water, are carefully examined. Some important observations on seal effects are drawn based on theoretical studies and FEKO simulations, which are also verified by experiments.

II. SEAL EFFECTS

The seal effects on the WPT system are analyzed by a full-wave electromagnetic simulator - FEKO, which is based on the method of moments (MoM). The model of the WPT system via magnetic resonance coupling in FEKO is shown in Fig.1. The transmitter (the driving coil and transmitting coil) or the receiver (the receiving coil and the load coil) are assumed to be sealed with a box which made of special materials. The geometrical and physical parameters of the WPT system are listed in Table I. Five sealing materials, Cu, ABS, earth, glass and sea-water, are considered. The parameters of sealing boxes are listed in Table II, where σ is conductivity and εr is relative permittivity. The geometrical parameters of the five sealing boxes are different, but the separations between the inner surfaces of the boxes and coils are the same.

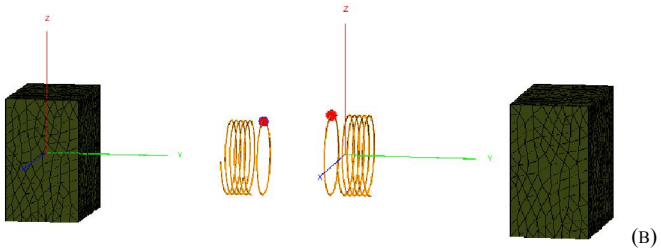

FIG.1 THE WPT SYSTEM MODEL IN FEKO (A) THE TRANSMITTER SEALED WITH A BOX (B) THE RECEIVER SEALED WITH A BOX

Table I
PARAMETERS OF THE WPT SYSTEM

Symbol	Meaning	Value	Unit
r1	Radius of driving coil	30	cm
r2	Radius of transmitting coil	30	cm
r3	Radius of receiving coil	30	cm
r4	Radius of load coil	30	cm
a	Cross-sectional radius of coil wires	0.3	cm
h	Height of the transmitting coil and the receiving coil	20	cm

N	Number of turns of the transmitting coil and the receiving coil	5.25	turn
RS	Internal resistance of voltage source	50	ohm
RL	Load resistance	550	ohm
d12	Distance between driving coil and transmitting coil	10	cm
d23	Distance between transmitting coil and receiving coil	150	cm
d34	Distance between receiving coil and load coil	10	cm

Table II
PARAMETERS OF THE SEALING BOXES

Parameter	Cu	ABS	Earth	Glass	Sea-water
σ(S/m)	5.8×107	/	0.02	/	4.788
εr	/	2.45	16	4.1	81
Length(cm)	54	60	60	54	70
Width(cm)	94	100	100	94	110
Height(cm)	94	100	100	94	110
Thickness(cm)	2	5	5	2	10

The simulation results by FEKO are shown in Table III. From Table III one can observe that the seal effects on the WPT systems via magnetic resonance coupling are great. The efficiency of unsealed WPT system is 88.24%, while the efficiencies of sealed WPT systems are all lower than that. The resonant frequency of unsealed WPT system is 9.9 MHz, and the resonant frequencies shifted in some cases of the WPT systems sealed by special materials. The efficiencies and resonant frequencies of the WPT systems with transmitter sealed or receiver sealed are similar.

Different sealing materials on the efficiencies and resonant frequencies of the WPT systems via magnetic resonance coupling are different. The efficiencies of the WPT systems sealed by Cu material are very low that the energy can hardly transfers wirelessly. The efficiencies of the WPT systems sealed by ABS material or glass material are the highest, just a little lower than the unsealed systems. But the resonant frequencies shift a little from 9.9 MHz to 9.84 MHz. The seal effects of earth are also large. The efficiency reduces to about 10% of the unsealed WPT systems. Sea-water has great impacts on the WPT systems, too. The efficiencies of the WPT systems sealed by it are as low as 7.5×10-2%.

Talble III
SIMULATION RESULTS

	Efficiency (%)	Resonant frequency(MHz)	Efficiency (%)	Resonant frequency(MHz)
Unsealed	88.24	9.9	88.24	9.9
sealed	Transmitter sealed		Receiver sealed	
Cu	32.98×10-7	9.9	1．79×10-10	9.9
ABS	85.56	9.9	87.19	9.84
Earth	10.57	9.9	8.15	9.9
Glass	79.71	9.84	82	9.9
Sea-water	7.5×10-2	9.9	7.23×10-2	9.9

III. PRACTICAL VERIFICATION

As discussed above, the seal effects of ABS is minimal among the five materials. It is very useful in many applications. The WPT systems via magnetic resonance coupling can be protected by sealed with ABS material without much change of performances. Experiments have been carried out to verify the studies above by using a four coil WPT system via magnetic resonance coupling, as shown in Fig. 2. The four coils of the WPT system via magnetic resonance coupling are sealed in ABS boxes. The LEDs are lighted with a little brightness change through the WPT system via magnetic resonance. The phenomenons proved that there are a little seal impacts of ABS boxes on the efficiencies and resonant frequencies of the WPT systems via magnetic resonance coupling .

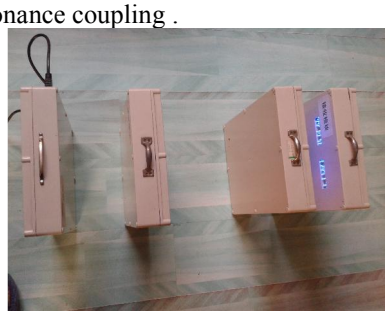

FIG.2 THE WPT SYSTEM SEALED BY ABS BOXES

IV. CONCLUSION

Seal effects of Cu, ABS, earth, glass and sea-water materials on the four-coil wireless power transfer (WPT) systems via magnetic resonance coupling are studied in –depth here. It was found that ABS and glass have little seal effects on the efficiencies and resonant frequencies of WPT systems. The efficiencies of WPT systems sealed by Cu material, earth material and sea-water material will decrease dramatically, and the WPT systems sealed by Cu can hardly transfer energy wirelessly. Therefore the WPT systems can be protected by sealed with ABS or glass materials, and should avoid to be sealed with Cu material.

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