코어를 사용한 새로운 자기공진형 코일구조

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A New Coil Set with Core for Magnetic Resonant Systems

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ABSTRACT

A coupled magnetic resonance system (CMRS) using compact coil sets with core driven by a class-E inverter was proposed. The source and load coils of conventional CMRS were replaced with two coils containing core so that the system can be quite compact in size and easy to design due to a resonance frequency for all resonant tanks regardless of coupling factor. Experiments for 500 *kHz* switching frequency show 40% system efficiency.

I Introductions

Lots of CMRS have been proposed in numerous literatures for practical applications, however, they still have many problems. First, the system is too bulky and complicated due to multiple magnetic couplings. Second, the system is extremely sensitive to environment and the power ratings of resonant capacitors are too large because of very high quality factor of 1,000~3,000. Third, the power efficiency of the system is very low, which partially stems from the use of low efficiency analog amplifiers such as RF amps. Finally, the design of CMRS is too complicated and uses superficial parameters such as scattering matrix and coupling coefficient, causing difficulties in practical implementation.

In this paper, a new CMRS scheme using two compact transformers and lumped capacitors is proposed, which has only a magnetic coupling through air like conventional inductive power transfer systems, and the system is no longer sensitive to environmental changes such as temperature and humidity. A high efficiency class-E inverter was used to due to its simplicity and zero voltage switching (ZVS) capability. Detail circuit-parameter-based model [1] is used to analyze the proposed CMRS. Hence, high output power and efficiency conditions are explicitly found and verified by experiments.

II Static Analysis of the CMRS

The design of a CMRS involves enormous number of circuit parameters even though the T_X and R_X of the system are symmetry, as shown in Fig. 1. They can be, however, classified into the hard parameters that are difficult to change and the soft ones that are easily manageable. The former includes the distance between T_X and R_X coils d, the diameters of them ϕ, and the switching angular frequency ω_s. The latter includes the numbers of turns of the source, load, and coupling coils, i.e. n_1, n_2, and n_0, respectively. Hence, the design can be focused on the determination of the numbers of turns for maximizing the efficiency or output power for the given source voltage V_s and output resistor R_{out}. The proposed CMRS is composed of a class-E inverter, a T_X coil, an R_X coil, lumped capacitors C_T, C_R, C_L for resonating, an output resistor R_{out}, and the source and load transformers, which include high permeability core so that they may deliver power to the T_X and R_X coils no longer through magnetic field but through electric voltage. Fig. 1 shows the circuit schematic of the proposed CMRS. The output power and efficiency of the system can be calculated from Fig. 1, respectively, as follows.

$$P_{out} = \frac{n_2^2 \omega_s^4 L_{mT}^2 L_{mL}^2 V_T^2 R_{out}}{\left\{ n_2^2 R_{out} \left(r_T r_R + \omega_s^2 L_{mT}^2 \right) + r_T \omega_s^2 L_{mL}^2 \right\}^2} \quad (1)$$

$$\eta = \frac{n_2^2 \omega_s^4 L_{mT}^2 L_{mL}^2 R_{out}}{\left(n_2^2 r_R R_{out} + \omega_s^2 L_{mL}^2 \right) \left\{ n_2^2 R_{out} \left(r_T r_R + \omega_s^2 L_{mT}^2 \right) + r_T \omega_s^2 L_{mL}^2 \right\}} \quad (2)$$

III Experimental Verifications

The parameters of the proposed CMRS are given in the Table II. The load power and efficiency were measured for wide range of values of load resistor from 10 Ω to 500 Ω when n_2 is 3, as shown in Fig. 2. The maximum power was achieved more than 1 W. The highest coil to coil efficiencies of 40% was obtained when R_L =30 Ω, n_2 = 3.

IV Conclusions

The proposed compact CMRS was completely analyzed and verified by experiments. The proposed source and load impedance transformers including cores can make the system quite compact and robust to environmental changes. High efficiency and large load power can arbitrarily be achieved by appropriate selections of the number of turns of coils.

References

[1] Jin Huh,Wooyoung Lee, Suyong Choi, Gyu-Hyeong Cho, Chun-Taek Rim, "Explicit static circuit model of coupled magnetic resonance system," *Power Electronics and ECCE Asia (ICPE & ECCE), 2011 IEEE 8th International Conference,* pp. 2233-2240, May 2011.

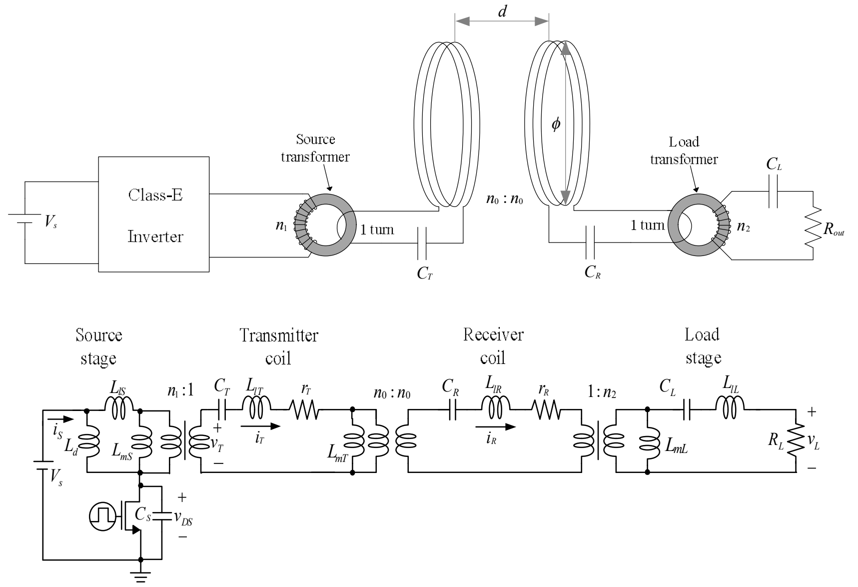

Fig. 1. Proposed CMRS with two source and load impedance transformers and class E inverter and its equivalent circuit.

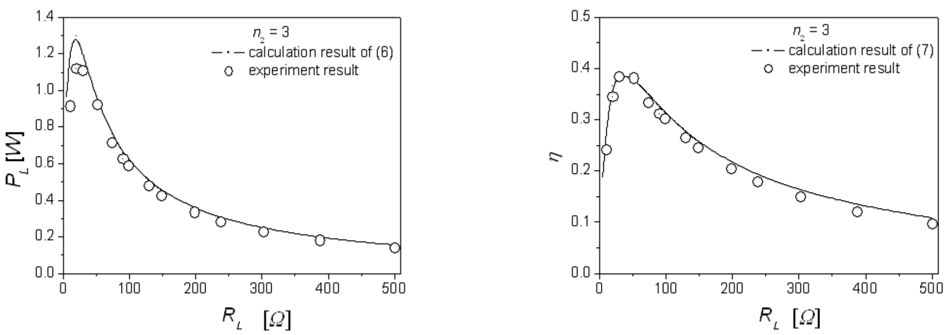

Fig. 2. Experimental result of the CMRS: power and efficiency

Table. Measured circuit parameters used in the experiment.

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
L_{mLo}	2.50 μH	L_{mTo}	0.045μH	r_T	5.37 Ω	C_R	1.68 nF
L_{mS}	40.0 μH	L_T	58.1 μH	r_R	6.92 Ω	C_L	4.22 nF
L_{mL}	22.5 μH	L_R	60.3 μH	C_T	1.74 nF	C_S	0.91 nF