IJCTA, 9(37) 2016, pp. 883-887

Individual Control of Multiple Microrobot using Selective Resonance based Wireless Power Transfer Coil System

R. Narayanamoorthi*, A. Vimala Juliet*, K. Vijayakumar* and K. Selvakumarn*

Abstract: Selective control of multiple microrobots are essential in biomedical and microfluid engineering. In a multiple microrobot system selective control and uniform power distribution at a high efficiency rate is a puzzling concern for the designer. In this paper selective control of individual robot is introduced using wireless power transfer circuit. By designing the robots with different resonant frequency and transferring the power to selected robots will help to control the motion. The selective transfer method will minimize the effects of cross coupling between the robots and unbalanced power division between the receiver.

Keywords: Microrobots, selective control, Wireless Power transfer, Resonance.

1. INTRODUCTION

Microrobots are becoming one of the potential social and scientific impact in healthcare and biomedical applications. As compared with conventional medical devices such as catheters and endoscopes, microrobtos could access small and complex regions of the human internal body system such as brain, spinal cord, blood vessels, inside the eye and gastrointestinal(GI) track [1]- [2]. Capsule endoscope(CE) pill are commercialized and used in hospitals, which has on board camera, actuator unit and wireless image transmission unit. However, CE pills are limited with passive monitoring of GI track and no control over functions, position and orientation. Also it is mandatory to include some sophisticated functions like active locomotion, drug delivery, biopsy, and multi-function monitoring and treatment. But powering of these devices is challenging, the traditional method using button battery cannot charge sophisticated microrobot for longer duration. Many literatures have addressed different methods of actuating the microrobots, such as attaching swimming bacteria to a microstructure [3], chemical reactions [4], but these methods require external electric or magnetic field to navigate also it has complex control mechanism. Magnetic actuation is the better choice for the manipulation of microrobot and it offers many advantages as compared with above mentioned methods. It can be controlled with or without line of sight and magnetic fields are safe to tissues and cells [5]. However, the produced dc magnetic field delivers propulsion without delivering any electrical power to the system, which makes the microrobots to perform only simple task like navigation and orientation control. The next ideal choice in the researcher view is the use of wireless power transfer technology, which can deliver electric power and simultaneously generate the propulsion force for the navigation. In [6], use of flexible ferrite sheets as a shielding material to disturb the balance of Lorentz force for the propulsion force generation. In Most of the applications majority of the operations are done with human control, with the inventions in camera and vision technology can makes the microrobot as autonomous. The autonomous microrobots can be used to perform parallel and multi-functional task with improved efficiency. These capabilities will enable a swarm of functionalized micro robots able to sense and manipulate a variety of environments [7]. A variety of methods have been demonstrated for the control of multiple magnetic micro robots. Magnetic actuation is an effective method for applying large forces,

* Faculty of Engineering and Technology, SRM University, Kattankulathur 603203, India.

but individually addressing magnetic robots is challenging because magnets respond similarly in a global field.

2. MAGNETIC PROPULSION FORCE GENERATION USING WPT CIRCUIT

The concept of a WPT system is shown in Figure 1. In a typical WPT system, when the time-varying current flows in a source coil, a magnetic field is generated, and then the generated magnetic field induces a current in the load coil, referred to as load current. Figure 1(b) shows the equivalent circuit of WPT. The relationship between the source current and the load current is described as

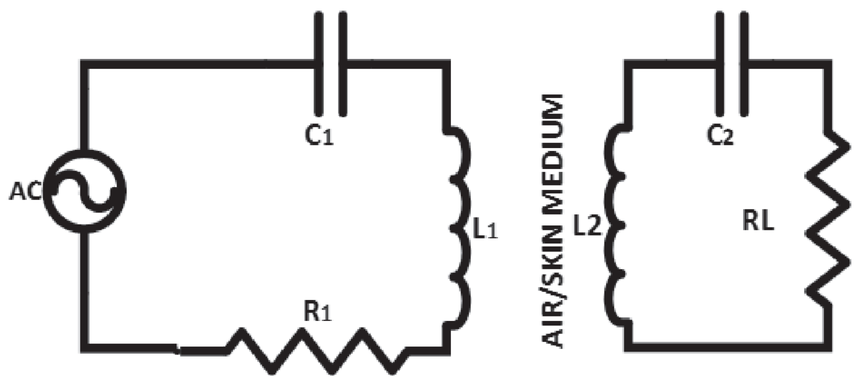

Figure 1: Conventional WPT circuit

$$F = I_1 I_2 \frac{\partial M}{\partial Z} \tag{1}$$

$$F = 2\pi K I_P I_S \cos\alpha \tag{2}$$

$$T = 2rBIl \sin\alpha \tag{3}$$

Where I_L and I_S denote the phasor forms of the load coil current and the source coil current respectively. L_1, R_1, C_1 indicate the inductance, resistance, and capacitance of the source coil, respectively, and L_2, R_2, C_2 represent the inductance, resistance, and capacitance of the load coil, respectively. M is the mutual inductance between the source coil and the load coil, and ω is the angular frequency. The maximum power is transferred at the resonance frequency, where the reactance of L_1, L_2 cancel out each other. The idea for generating propulsion force comes from an electromagnet consisting of closed-loop coils [8]. If the source coil and the load coil flow a time-varying current, they behave as an electromagnet, which can generate repulsive force and attractive force. When the incident magnetic field flows in the closed loop, each segment of the closed loop generates Lorentz force, which evidently can become a source of torque.

3. SELECTIVE CONTROL OF MICROROBOT

Figure 2 represents the single transmitter and three receivers for three coil WPT system, where the transmitter, driver and load coils are represented with the subscript of 1, 2_i, 3_i (where $n = 1,2,3$) respectively [9].

The resonance of the system is achieved by

$$f_1 = \frac{1}{2\pi\sqrt{L_1 C_1}} = \frac{1}{2\pi\sqrt{L_{2i} C_{2i}}} = \frac{1}{2\pi\sqrt{L_{3i} C_{3i}}} \tag{4}$$

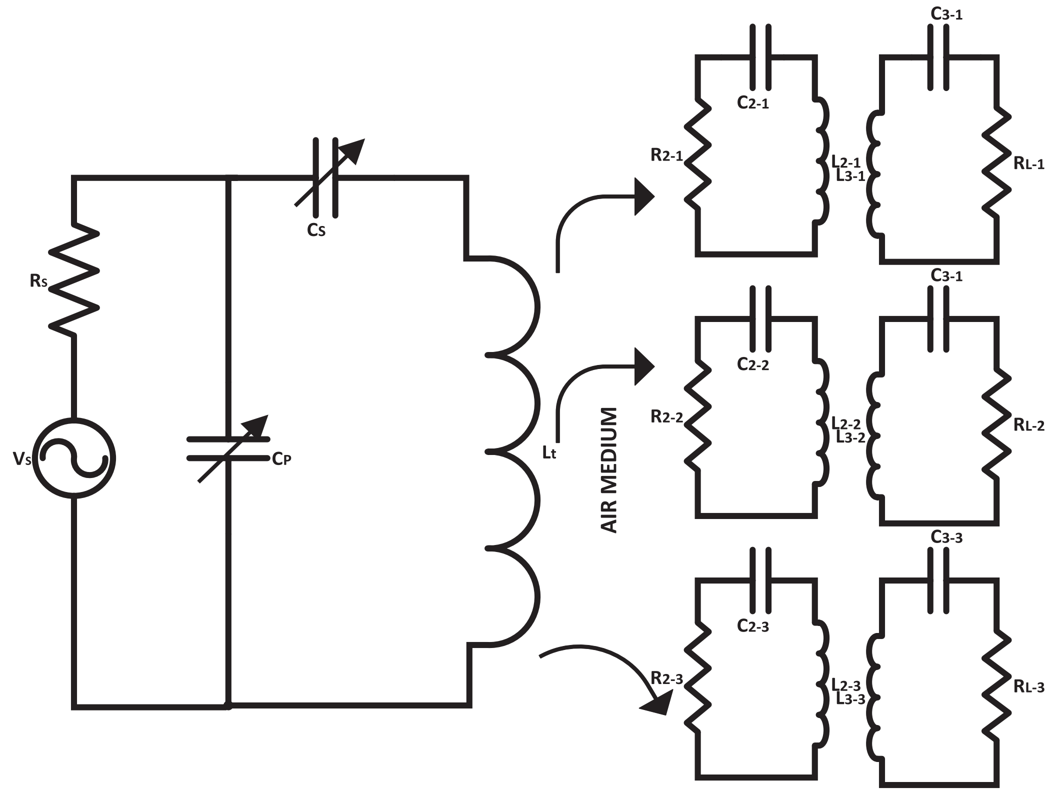

Figure 2: Multiple receiver WPT System

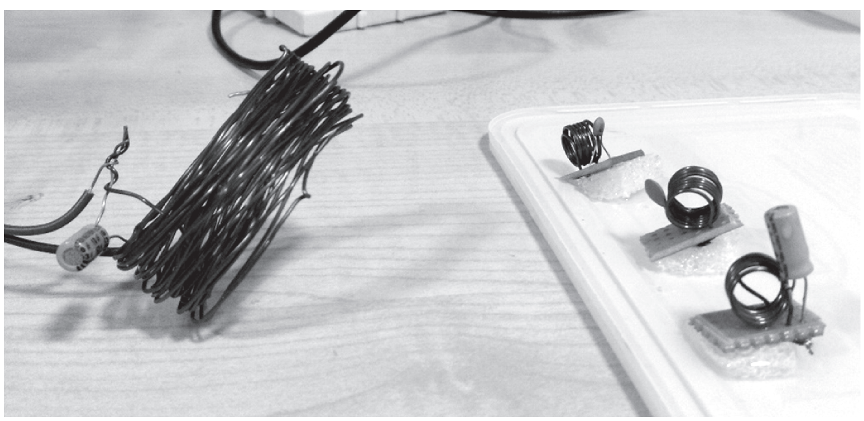

Figure 3: Selective Transfer without medium

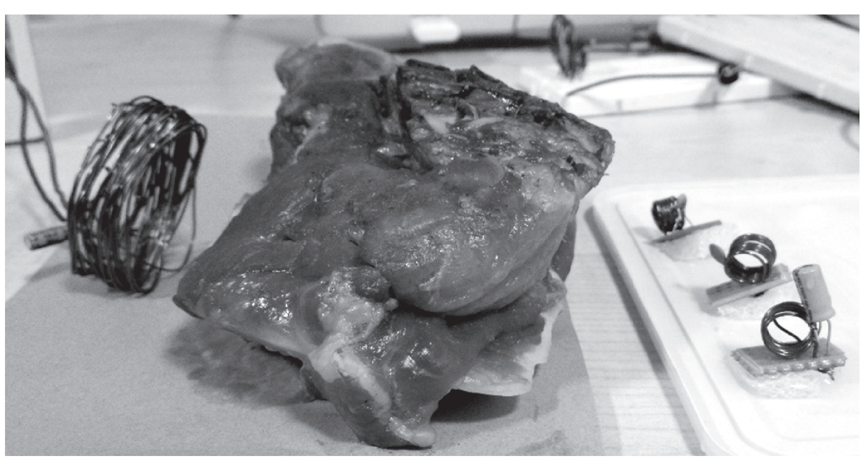

Figure 4: Selective Transfer with tissue medium

Figure 3 and 4 shows the experimental setup of the proposed system and the output voltage of receiver 1 is shown in Figure 5 and 6 for the distance of 3 and 5c.m between transmitter and receiver coil.

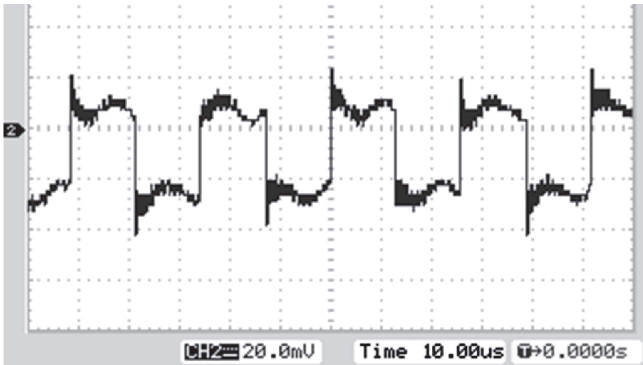

Figure 5: Receiver 1 Output Voltage

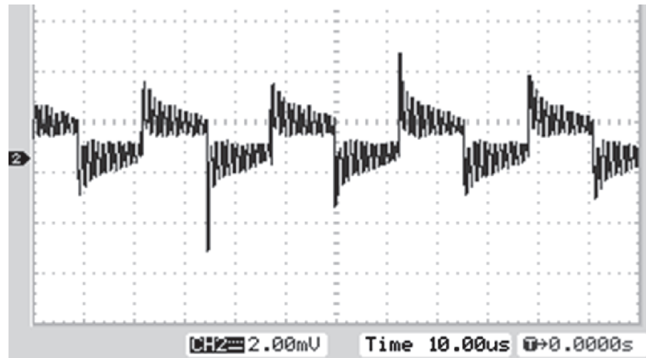

Figure 6: Receiver 2 Output Voltage

When the receiver coil 1 is changed dynamically changed with the distance of 3c.m to 5c.m and 5c.m to 3c.m the variation in the output voltage is shown in Figure 7. If receivers 2 and 3 are placed at 90 degree to the transmitter and receiver 1 is placed parallel with the transmitter the output voltage of receiver 1 (Figure 8) is higher as compared with the receiver 2 and 3 voltage (Figure 9), due to reduction in the coupling between the Tx and Rx2 and Rx3 are reduced.

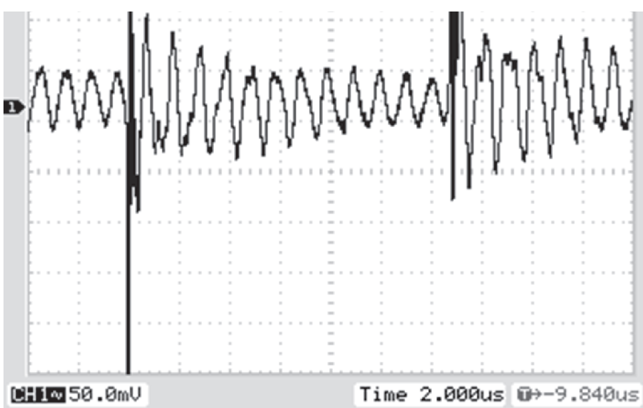

Figure 7: Rx1 Voltage at under dynamic variation

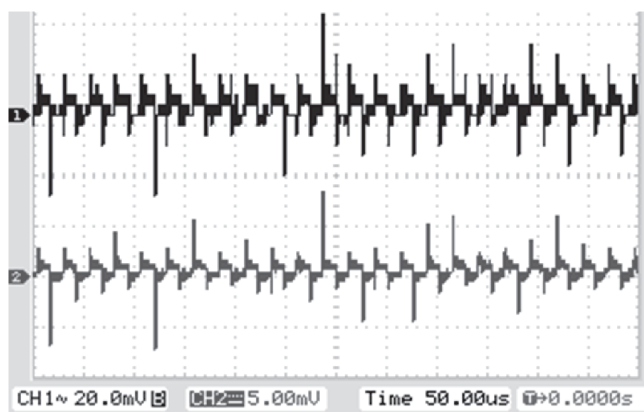

Figure 8: Rx 2 and 3 Voltage

4. CONCLUSION

Selective Magnetic resonance based WPT system with single transmitter and multiple receiver system to control the microrobot is discussed in this paper. By designing the receivers with different resonant frequency and tuning the transmitter to the particular frequency the receiver selection can be achieved. Also in this paper a three coil inductive link is analysed for the multiple receiver system, which gives an increase in power delivered to receiver and improves the overall system efficiency as compared with two coil multiple receiver inductive link. The experimental results show the multiple receiver WPT system gives efficiency of 64% under static conditions and 51-54% for the variation of distance between 3 to 5 cm.

Referencs

1. S. Y. R. Hui, W. Zhong and C. K. Lee, "*A Critical Review of Recent Progress in Mid-Range Wireless Power Transfer*," in IEEE Transactions on Power Electronics, Vol. 29, No. 9, pp. 4500-4511, Sept. 2014.

2. R. Narayanamoorthi, A. Vimala Juliet et al., "*Efficient Wireless Power Transfer System for Generation of Magnetic Propulsion Torque for Microrobot*", International Journal control theory and applications 9(16), 2016, pp. 8115-8124.

3. R. Narayanamoorthi, A. Vimala Juliet et al., "*Hybrid Energy Storage Devices based TET system design for Powering the ICP Devices*", International Journal control theory and applications 9(16), 2016, pp. 8061-8070.

4. A. Dominic Savio, R. Narayanamoorthi et al., "*PSO based Matching Circuit tuning System for Magnetic Resonance Based Wireless Power Transfer in Biomedical Implants*", International Journal control theory and applications 9(16), 2016, pp. 8153-8158.

5. X. Liu, "Qi Standard Wireless Power Transfer Technology Development Toward Spatial Freedom," in IEEE Circuits and Systems Magazine, Vol. 15, No. 2, pp. 32-39, Second quarter 2015.

6. R. Narayanamoorthi, A. Vimala Juliet et al., "*Frequency Split Elimination of Short Range Wireless Power Transfer System by Active Matching Tuning Circuit*", Indian Journal of Science and Technology, Volume 9, Issue 36, September 2016.

7. R. Narayanamoorthi, A. Vimala Juliet et al., "*Experimental Analysis of 2, 3 and 4 coil wireless power transfer system with different medium and distance*", Indian Journal of Science and Technology, Volume 9, Issue 35, September 2016.

8. J. P. K. Sampath, D. M. Vilathgamuwa and A. Alphones, "*Efficiency Enhancement for Dynamic Wireless Power Transfer System With Segmented Transmitter Array*," in IEEE Transactions on Transportation Electrification, Vol. 2, No. 1, pp. 76-85, March 2016.

9. G. Yang, C. K. Ho and Y. L. Guan, "*Dynamic Resource Allocation for Multiple-Antenna Wireless Power Transfer*," in IEEE Transactions on Signal Processing, Vol. 62, No. 14, pp. 3565-3577, July 15, 2014.