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Wireless Power Transfer Through Inductive Coupling For Aimds

Deepali A. Newaskar, B. P. Patil

Abstract: ***For the patients with some cardiovascular diseases, implantable devices like implantable cardiac pacemakers and implantable cardioverter defibrillators play a very important role. The life of implantable device is limited by the life of battery and the size of implanted device is dependent on size of battery. More life of battery demands larger battery size. Since these devices are implanted inside the human body, they must be small in size as well as of long battery life. Wireless re-charging of such devices can only be the solution to reduce the size and increase life of AIMDs. Wireless recharging by magnetic resonance coupling in less time is expected and hence this topic is considered for more research to have uninterrupted power supply from battery. Selection of operating frequency for transfer of power wirelessly is of great concern as it requires attention towards certain guidelines as basic restrictions provided by International Commission on non-ionizing Radiation Protection (ICNIRP). With lower frequencies used for power transfer, the efficiency would be less whereas with higher frequencies efficiency would be higher but with the use of higher frequencies for power transfer certain biological issues needs attention like tissue heating. In the technique of wireless power transfer, the transmitting coil is assumed to be outside the body and receiver coil is considered to be inside the human body above the pacemaker shell. The efficiency of power transfer is affected by frequency for power transfer and distance between the two coils.***

Keywords—implantable cardioverter defibrillators, implantable cardiac pacemakers, operational frequeny, wireless charging, wireless power transfer.

I. INTRODUCTION

T he major functions of Active implantable medical devices (AIMDs) are

- Delivering electrical signals to some tissues or organs and
- Monitoring certain relevant parameters or signals.

Batteries used in implantable devices are of great concern for manufacturers and thus a kind of scope for researchers. Life of active implantable medical device (AIMD) depends on the life of battery. Cardiac pacemakers now a day make use of Lithium Iodine battery which possesses two excellent characteristics such as slow self discharge rate and stable or constant voltage supply through much of the useful life. With these two characteristics, it acts as an excellent power source for cardiac pacemaker applications. The shelf life of Lithium Iodine battery is around ten to twelve years. If by wireless power transfer the AIMD battery is recharged then the size of the AIMD can be reduced as battery consumes more space in any implantable device than other circuitry and so the size of implantable medical device is majorly dependent on the size of battery. Patients implanted with pacemaker or any other AIMD would not required to undergo further surgical treatment which could be life threatening for replacing the unit. To avoid the surgical treatment for the second time, which can be life threatening too, wireless charging of AIMD can be the best solution.

In vitro energy supply seems to be the best solution for researchers. With wireless charging, rechargeable batteries can replace primary batteries, wherein receiving circuit on the pacemaker will receive energy through electro-magnetic induction principle from transmitter coil placed outside or on the body. The primary circuit may receive energy from either sunlight (through solar cells) or through external battery or power supply [1]-[4].

Energy transfer through electro-magnetic induction principle can be of two types, non-resonance and the magnetic coupling resonance (MCR). In both types of wireless charging systems, a transmitting coil will be placed outside the body (vitro) and the receiving coil will be placed inside the human body (vivo). Pacemaker circuitry is hermitically sealed inside a titanium alloy case since titanium is ten times stronger than steel but it is very lighter than steel and is bio-compatible with the human body. The receiving coils must be placed outside the pacemaker shell made of titanium alloy, as the titanium alloy has property to avoid external electromagnetic interference [5].

Wireless charging system based on non- resonant type induction principle has low power transfer efficiency as compared to MCR-WPT. So to improve power transfer performance, ferrite core chunks are generally used which causes the system to be bulky having large volume and mass. So such systems are difficult to place inside the body of a human being. Whereas, in the MCR-WPT system, in vitro energy supply seems to be the best solution for researchers. With wireless charging, rechargeable batteries will replace the primary batteries, wherein receiving circuit on the pacemaker will receive energy through electro-magnetic induction principle from transmitter coil placed outside or on the body. The primary circuit may receive energy from either sunlight (through solar cells) or through external battery or power supply. Energy transfer through electro-magnetic induction principle can be of two types non-resonance and the magnetic coupling resonance (MCR) [6]-[8].

In MCR-WPT, it is very critical to design the coils.

The selection of operational frequency used for power transfer is one of the most important aspects. The magnetic field will have more penetration inside the body with lower frequencies, but the performance of power transfer will be compromised in terms of efficiency and transferred power.

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So, more time will be required for charging. Whereas, higher frequencies used for power transfer will need less time for charging but it will cause eddy current losses, will cause tissue heating, and generate electromagnetic compatibility (EMC) issues in the electronic circuitry of the AIMD.

II. BASIC RESTRICTIONS WHILE SELECTING FREQUENCY FOR POWER TRANSFER

As per ICNIRP guidelines, restrictions on the effects of exposure as per established health effects and are called as basic restrictions. Depending on frequency, the basic restrictions are provided on some physical quantities like Specific Absorption Rate (SAR), current density and power density. To avoid adverse health effects, these basic restrictions should not be exceeded.

- For the frequencies in the range of 1 Hz and 10 MHz, basic restrictions are provided on current density which otherwise may affect on nervous system functions;
- For the frequencies in the range of 100 kHz and 10 GHz, basic restrictions on SAR are provided to prevent excessive tissue heating and heat stress; for frequencies in the 100 kHz–10 MHz range, basic restrictions are mentioned for SAR and current density ;
- For the frequencies from 10 and 300 GHz, basic restrictions are mentioned for power density to prevent excessive tissue heating on the surface of body [9],[10].

III. EXPERIMENTAL SETUP AND RESULTS

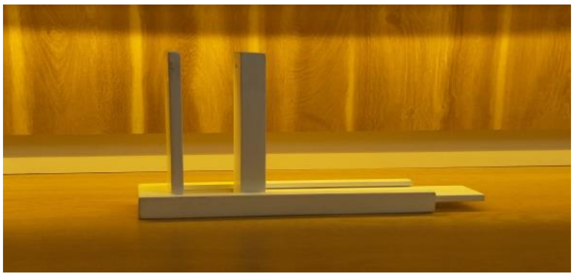

Fig.1: Testing Jig

Experimental setup is made as shown in Fig. 1 to mount primary and secondary coils. Secondary coil will be placed inside the human body so it is placed at constant position. Primary coil will be outside the human body and is movable to change the distance between two coils.

Fig. 2 shows different Solenoid coils made with different radius and experimentation.

Case I: Initially two solenoid coils are considered with specifications as

Primary coil: N1=50, radius=2cm having L1=8.56mH; Secondary coil: N2=50, radius =2cm having L2=8.22mH;

Input Voltage applied =10Vpp sine wave with different frequencies from Aplab 3 MHz Signal Generator. During experimentation temperature was 27°C and humidity was 37%. Output peak to peak voltage generated was observed on TektronixTBS1062 DSO. Table I shows different set of

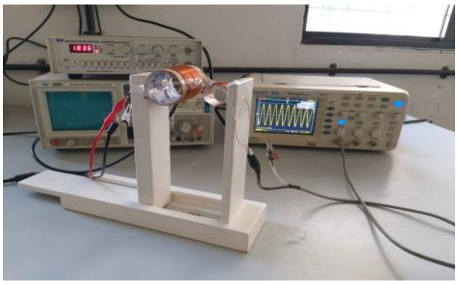

Fig.2: Setup with transmitter and receiver as solenoid coils.

readings taken by varying the distance between two coils and by varying frequencies by keeping constant input voltage. Output voltages are measured as mV peak to peak.

Table I: Voltage(mV) generated at secondary coil for different distances and Frequencies(MHz)

Dist (cm)	Frequency (MHz)											
	0.2	**0.3**	**0.5**	**0.8**	**1**	**1.2**	**1.5**	**1.7**	**2**	**2.2**	**2.5**	**3**
0.7	438	470	504	508	712	904	1900	5640	1000	544	288	128
1	352	416	456	520	616	392	1630	4800	872	480	256	112
1.1	352	408	448	512	600	768	1610	4360	848	464	240	104
1.2	312	384	424	488	576	768	1560	3760	800	432	224	96
1.5	280	344	376	424	496	632	1320	3080	696	384	208	96
2	224	288	320	360	424	528	1100	2920	576	320	176	80
2.5	128	216	240	272	312	392	816	2920	424	240	128	64
2.7	112	184	224	256	296	368	744	2760	384	208	112	56
3			200	224	264	328	656	2680				
3.3							620	2560				
3.5							720	2440				
3.6							580	2240				
4								2080				
4.3								2080				
4.5								2080				
4.7								2000				
5.2								1800				
5.3								1840				
5.5								1640				
5.7								1440				
6								1480				
6.5								1480				
7								1280				
7.5								1280				
8.5								1360				
10								1120				

Fig. 3 shows graph of output voltage generated in mVolts by varying distance between two coils at different frequencies specified in MHz. It has been

observed that the maximum output voltage is generated for 1.7 MHz. So it can be termed as resonating frequency. Fig 4 shows the same graph just for three frequencies. Fig. 5 shows graph for output voltage at different frequencies by keeping distance between two coils as constant i.e. 1 cm.

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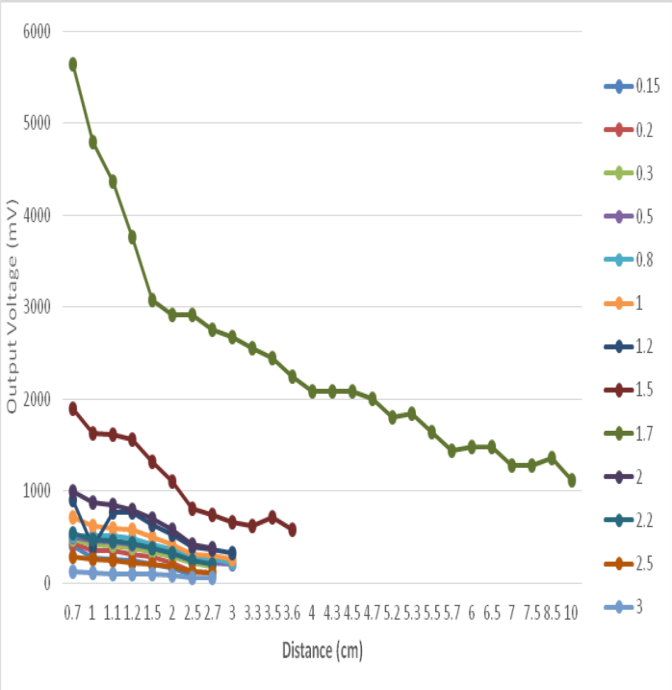

Fig.3: Output Voltage (mV) Vs distance (cm) between two coils at different frequencies(MHz).

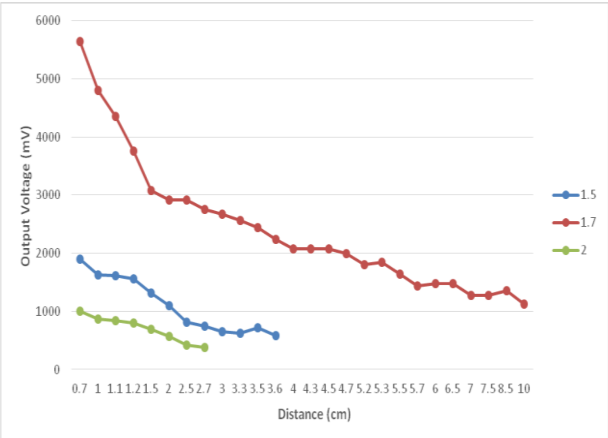

Fig.4: Output Voltage (mV) Vs distance (cm) between two coils at three different frequencies 1.5MHz, 1.7MHz, 2MHz .

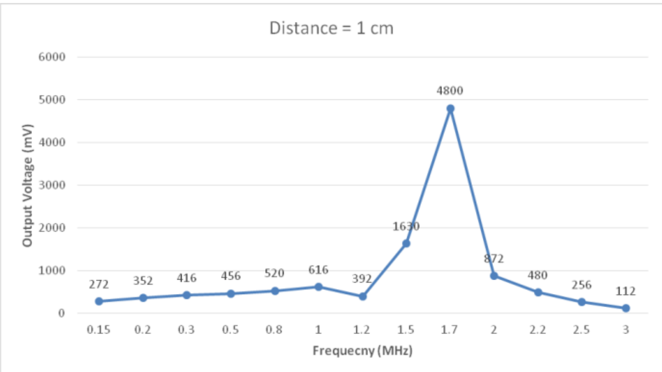

Fig. 5: Output Voltage at different frequencies by keeping distance between two coils as constant i.e. 1 cm.

Case II: Two solenoid coils with N1=50, radius1=2cm having inductance L1=8.56mH and secondary coil with N2=30, radius2=1.25cm having inductance L2=70.9μH are considered. Input sinusoidal signal of 10Vpp with different frequencies is applied through Aplab 3MHz Signal Generator. At the time of experimentation temperature was 22°C and humidity was 59%. For observation of output Aplab DSO is used. Table V shows output voltage readings obtained for 3MHz frequency. Fig. 6 shows graph plotted for output voltage (mV) versus distance between two coils (cm).

Table II: Output voltage generated for secondary solenoid coil with N2=30

Distance (cm)	Vopp(mV) At 3MHz
0.7	1030
1	640
1.1	800
1.2	760
1.5	568
2	408
2.5	384
3	512
3.3	480
3.5	440
3.6	432
4	416
4.3	400
4.5	384
4.7	352
5.2	320
5.3	312
5.5	296
5.7	288
6	264
6.5	236
7	200
8	136
9	120
10	116

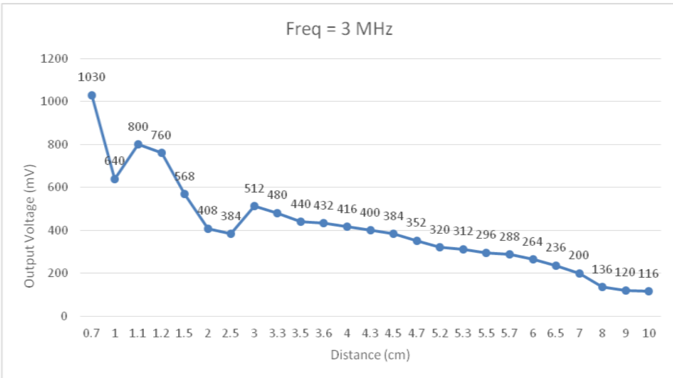

Fig 6: Graph showing Output Voltage generated for 3MHz frequency varying distance between two coils(cm).

IV. CONCLUSIONS

- Output voltage generated is directly proportional to distance between the two coils as maximum emf will be induced if coupling coefficient is maximum and emf induced is maximum near resonance frequency.

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- For wireless power transfer, selection of frequency is a critical task. It needs attention to certain parameters like current density, power density, specific absorption rate as they can cause serious health issues like problems related to nervous system, tissue damage by excessive heating.
- Power transfer efficiency can be improved by certain compensation circuits.

REFERENCES

1. T. Campi, S. Cruciani, V. De Santis, F. Palandrani, A. Hirata, and M. Feliziani, "Wireless power transfer charging system for AIMDs and pacemakers," IEEE Trans. Microw. Th. Techn., vol. 64, no.2, pp. 633-642, Feb 2016.
2. T. Campi, S. Cruciani, G. P. Santilli, and M. Feliziani, "Numericalanalysis of EMF safety and thermal aspects in a pacemaker with awireless power transfer system," in IEEE Wireless Power Transfer Conf., Boulder, CO, USA, May 13–15, 2015, pp. 1–4.
3. Z. Xiu, S. L. Ho, and W. N. Fu, "A hybrid optimal design strategy of wireless magnetic-resonant charger for deep brain stimulation devices," IEEE Trans. Magn., vol. 49, no. 5, pp. 2145–2148, May 2013.
4. B. P. Patil, Deepali Newaskar,Kunal Sharma, Tarun Baghmar Mahesh Ku. Rajput," Effect of number of turns and medium between coils on the Wireless Power Transfer efficiency on AIMD's" Biomedical Engineering: Applications, Basis and Communications ,Vol. 31, No. 02, 2019.
5. Chunyan Xiao, Kangzheng Wei, Dingning Cheng and Yufeng Liu, "Wireless Charging System Considering Eddy Current in Cardiac Pacemaker Shell: Theoretical Modeling, Experiments and Safety Simulations", IEEE Trans. Ind. Electx., DOI 10.1109/TIE.2016.2645142.
6. V. S. Mallela, V. Ilankumarand and N.Srinivasa Rao,"Trends in Cardiac Pacemaker Batteries," Indian Pacing and Electrophysiology Journal (ISSN 0972-6292), vol. 4, pp. 201-212 , 2004.
7. Achraf Ben Amar, Ammar B. Kouki and Hung Cao, "Power Approaches for Implantable Medical Devices", Sensors 2015, ISSN 1424-8220.
8. Chunyan Xiao, Dingning Cheng and Kangzheng Wei, "An LCC-CCompensated Wireless Charging System for Implantable CardiacPacemakers: Theory, Experiment and Safety Evaluation", DOI
9. 1109/TPEL.2017.2735441, IEEE Transactions on Power Electronics.
10. Int. Commission Non-Ionizing Radiat. Protection, "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)," Health Phys., vol. 74, pp. 494–522, 1998.
11. IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE Standard C95.1, 2005. Int. Commission Non-Ionizing Radiat. Protection, "Guidelines for limiting exposure to time-varying electric and magnetic fields for low frequencies (1 Hz-100 kHz)," Health Phys., vol. 99, pp. 818–836, 2010.

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