

A Magnetic Sensor based Auto-tracking system for 2.4 GHz Near-field Phased-Array based Wireless Power Transfer System in Neuromodulation Applications

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Abstract—This paper presents a magnetic sensor based auto-tracking method for a phased array based wireless power transfer system to be implemented in neuromodulation applications. This method is proposed to track the position of the receiver (placed on a freely moving animal) and transmit the microwave signal with a focused beam to the target receiver. The coordinate locations of the target are obtained from the magnetic sensor and converted into phase information for the phased array. The system is constructed by a 2.4 GHz near-field 4×4 phased array transmitter antenna with 4-bit phase shifters. The phased array TX antenna steers the beam from -5° to -155° in the θ plane. The magnetic sensor can detect the location of the receiver and the in this steering range. The process of tracking the target and focusing the beam has been evaluated by simulation.

Index Terms—Magnetic sensor, phased array, wireless power transfer.

I. INTRODUCTION

With the advancement of the wireless power transfer (WPT) system, transferring continuous power to the low-power circuits such as implantable medical devices are becoming more prevalent in biomedical applications. The recent advancements in antenna miniaturization, circuit design, and biocompatible materials are opening new opportunities for subtle diagnosis of disease using wireless implantable devices [1]. In wireless power transfer system where the location of the receiver changes with time such as in case of freely moving rodents, UAV, it is important to track the target to reduce the power loss. There are several target detection methods, for example: satellite positioning, such as, radar positioning [2], optical positioning [3] etc.

Headstage-based wireless power transfer system has become one of the most popular methods for neural stimulation in recent times [4]. As the rodents are freely moving animals, the location of the receiver is not stable over time. In our prior work, a phased-array antenna based near-field radiative WPT system, where the power beam can be steered electronically towards the headstage of the freely moving rodent has been proposed [5]. The limitation of the prior work is it cannot detect the location of the receiver. To overcome this challenge, here we proposed a magnetic sensor based auto-tracking system which can detect the position of the receiver and send the focused beam toward it.

The novelty of this proposed work is- i) Achieving a wide range of steering angles in the receiver plane and ii) Building an algorithm for auto-tracking system.

II. SYSTEM OVERVIEW

The fundamental parts of the auto-tracking module are : A phased array transmitter antenna, 4-bit phase shifters and magnetic sensor.

A headstage needs to be used for freely moving rodents that includes the receiver, and the transmitter is placed on the top/bottom of the behavioral cage. The TX antenna resonates at 2.4 GHz ISM band which is suitable for biomedical applications. The TX antenna is a 4×4 phased array antenna to transmit wireless power through a unidirectional beam. The unidirectional beam reduces the power loss and focuses power towards the receiver properly. The proposed antenna array is designed on a 2.4 mm thick FR4 substrate with a dielectric constant of 4.3 and a loss tangent of 0.02. Copper (Cu) with a thickness of 0.018 mm has been chosen as the conductor for both the radiating patch and the ground patch.

To steer the unidirectional beam into different angles, different phases are given into the ports of the antenna and the input phases are represented in Table I. The input angles of commercially available MAPS-010144 digital phase shifter are used as different input phases of the transmitter.

The target surface location is divided into six coordinates based on the direction angle of the unidirectional beam. For the auto-tracking process, a small piece of neodymium magnet needs to be attached with the receiver externally. The magnetic sensor is connected to the transmitter antenna. The magnetic sensor includes commercially available monolithic MLX90363 Magnetometer IC. The MLX90363 is sensitive to three (B_X , B_Y and B_Z) components of the flux density applied to the IC. This allows the MLX90363 to sense any magnet moving in its surrounding and decode its position through an appropriate signal processing.

III. SIMULATION RESULTS

The computer simulation Technology (CST) software is used to carry out the simulation process. As the radiation beam is of narrow bandwidth, it cannot cover the entire area of the behavioral cage. So, the beam steering is needed for covering the maximum area of the cage. The radiation pattern of the transmitter antenna presents that it steers beam from is -5° to -155° in θ axis for the phase conditions given in table I. The results of four phase conditions are shown in Fig. 1. The steps of proposed auto-tracking method are shown in a flowchart in Fig. 2. After gathering the SPI information, the

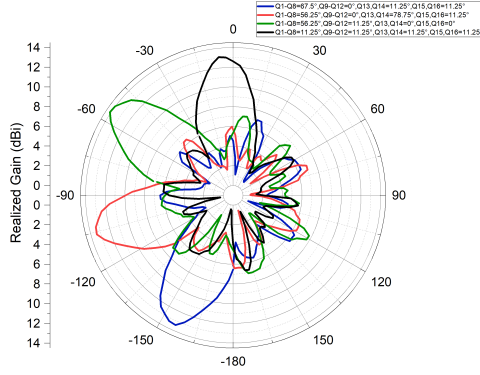


Fig. 1. Representation of beam-steering along θ plane in different positions

TABLE I
BEAM STEERING ALONG THE θ - AXIS FOR DIFFERENT PHASES

Input phases				Beam Direction	HPBW	Gain (dB)
Q1-Q8	Q9-Q12	Q13-Q14	Q15-Q16			
67.5°	0°	11.25°	11.25°	-155°	32.3°	13.4
45°	22.5°	67.5°	90°	-105°	32.5°	14.2
56.25°	0°	78.75°	11.25°	-95°	31.2°	14.1
0°	45°	56.25°	0°	-55°	34.4°	13.3
56.25°	0°	0°	11.25°	-35°	30.2°	13.1
11.25°	11.25°	11.25°	11.25°	-5°	34.4°	13.6

MSP432 calculates the corresponding coordinate and matches with current location. Based on the matching of the location, it sends command to steer the beam towards the target. The algorithm is developed in CCS (Code Composer Studio).

In Fig. 3, the responding angles of magnet to IC is presented. The magnetic sensor calculates the location of the receiver with a magnet, the IC will generate two angles in reference to X-axis to Y-axis and X-axis to Z-axis. Since the beam is steered to six locations, the corresponding angles are plotted in the Fig. 2. The figure represents the two angles as XY angle and XZ angle, where the XY angle only represents the receiver being in +Y or -Y as the x axis cannot change with beam steering. The YZ angle estimates the distance relative to the position of the sensor. While the position can be calculated with the YZ angle alone the XY angle acts as a validation test to make sure the beam is steered in the correct direction.

IV. CONCLUSION

A magnetic sensor based auto-tracking WPT system using a 4×4 phased array is designed and demonstrated in this proposed work. The system in this paper realizes the phase control on the X,Y and Z-axis. The detecting process gives 3D location of the receiver. In future, we will continue to increase the steering range and get more steering range to get the precise location of the receiver.

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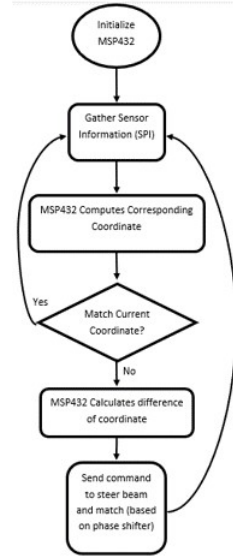


Fig. 2. Detailed flowchart of the auto-tracking process

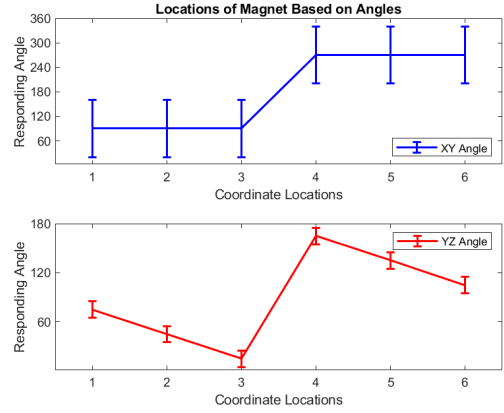


Fig. 3. Location of magnet based on angles

REFERENCES

- [1] X. Wei and J. Liu, "Power sources and electrical recharging strategies for implantable medical devices," *Frontiers Energy Power Eng. China*, vol. 2, no. 1, pp. 1–13, 2008.
- [2] M. Chiani, A. Giorgetti and E. Paolini, "Sensor Radar for Object Tracking," in *Proceedings of the IEEE*, vol. 106, no. 6, pp. 1022–1041, June 2018, doi: 10.1109/JPROC.2018.2819697.
- [3] L. Batistić and M. Tomic, "Overview of indoor positioning system technologies," 2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2018, pp. 0473–0478, doi: 10.23919/MIPRO.2018.8400090.
- [4] D. K. Biswas, J. H. Martinez, J. Daniels, A. Bendapudi, and I. Mahbub, "A novel 3-d printed headstage and homepage based wpt system for long-term behavior study of freely moving animals," in 2020 IEEE Radio and Wireless Symposium (RWS), IEEE, 2020, pp. 268–271.
- [5] N. Saha and I. Mahbub, "Design, Modeling, and Simulation of a 2.4 GHz Near-field Phased-Array based Wireless Power Transfer System for Brain Neuromodulation Applications," 2022 IEEE Texas Symposium on Wireless and Microwave Circuits and Systems (WMCS), 2022, pp. 1–5, doi: 10.1109/WMCSS55582.2022.9866412.