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Implantable Sensors and Antennas for Wireless Brain Care

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Abstract

Wireless implantable sensors brings the promising prospects for the treatment of intracranial diseases. To achieve the transcranial wireless links for data transmission between the implanted sensor and the off-body receiver, different approaches have been proposed in the literature. In this summary paper, we will introduce and briefly analyze the state of the art and then introduce two implantable battery-free systems for brain care application from our current research.

1. Introduction

Wireless health has tremendous potential to improve people's well-being fundamentally by making the healthcare more effective in terms of coverage, patient outcomes, and costs. Correspondingly, there is an immense need for innovations related to sensors, antennas, and RF electronics, because the existing technologies fall short in terms of wireless performance, energy consumption, and materials and structures, when applied in body-centric or biological environments. As shown in Fig. 1, during the past ten years, this need has resulted in a steep rise in the published research on wearable and implantable wireless devices that continues today.

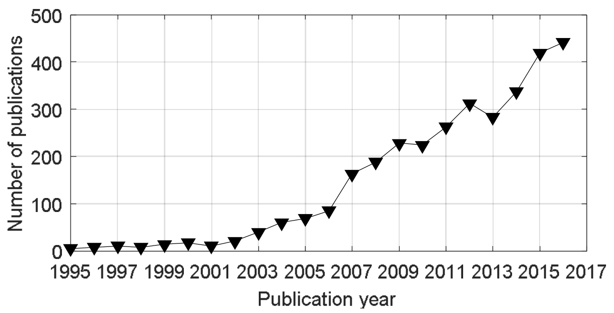
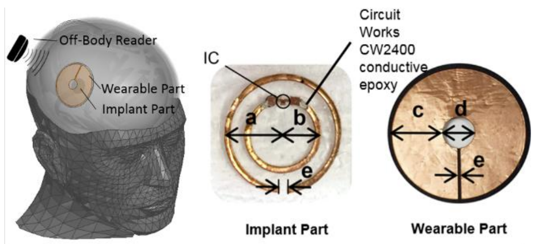


Figure 1. Journal and conference publications in Scopus citation database (7 Dec. 2017) with one of the words 'wearable', 'body-worn', 'implantable', 'implant', 'implanted' in the title and 'wireless' in title, abstract, or keywords.

The main implementation of implantable and wearable devices are for the establishment of the wireless physiological monitoring systems. In brain care, important applications include neuroprosthetics control , monitoring of intracranial pressure and cerebral oxygenation. To obtain the sampled signal with enough accuracy, the sensors of the aforementioned applications are usually required to be invasive. Meanwhile, to minimize the invasiveness, the implantable sensors needs to be remote-powered to avoid batteries and exhibit thin and flexible structure. This limitation brings big challenge to build the transcranial wireless links. To achieve this, some approaches has been proposed which include inductively linked implanted and wearable antennas [1] for power and data and dual-antenna implants [2] equipped with an additional far field antenna for an off-body data link.

In this paper, we will summarize two alternative methods to establish this transcranial wireless links for brain care applications. The first work is RFID inspired and the second is based on the fusion of the near field energy harvesting system and a far field data transmission system.

2. Split ring resonator RFID antenna systems for far field readable backscattering implants



Geometrical parameter (mm)	a	b	c	d	e
	8.6	5.7	20.8	12.6	1.0

Figure 2. Anatomical head model and prototyped antenna system with its geometrical dimensions.

To achieve an off-body readable system with a simple antenna-only wearable unit, we developed an antenna system adopted from the 3-ring planar split ring antenna structure by placing two inner rings (outer radius: 8.6 mm) inside the cranial cavity and larger outer ring (radius: 20.8 mm) on the head [3]. As shown in Fig. 2, in this approach, the implant part carries a backscattering microsystem, which in our demonstration is an RFID IC (NXP UCODE G2iL) having a wake-up power of −15.8 µW. The outer ring serves concurrently as a radiating element that establishes an off-body link for power and data at 915 MHz. The implant is patterned from copper on 50 µm thick flexible polyethylene (ε_r=2.25, tanδ=0.001 at 915 MHz) that was encapsulated in a 1-mm layer of silicone (ε_r=2.2, tanδ=0.007 at 915 MHz). The wearable part was patterned from copper foil on 2 mm thick EPDM (Ethylene-Propylene-Diene-Monomer) (ε_r=1.26, tanδ=0.007 at 915 MHz) substrate.

The prototype system we have tested in a liquid phantom provided the detection of ranges of 1.3 m, 1.1 m, and 0.7 m for the RFID implant under EIRP = 3.28 W emission regulation when the inner rings were at the depths of 5 mm, 10 mm and 15 mm, respectively, in the tissue mimicking liquid. In the meeting, we will present further data from both from modelling and testing that validates the applicability of the system under non-ideal operating conditions including translational and rotational misalignment between the implanted and wearable parts as well as the placement location and antenna orientation with respect to the head.

3. Implantable fusion system of near-field and far-field links for intracranial pressure monitoring

We developed this system targeted for the monitoring of intracranial pressure (ICP), which is a life-saving activity that is required in management of many brain diseases and injuries [4]. The battery-powered implant [5] has large size with limited lifespan and the fully-passive approach [6] has unsatisfactory read range due to the zero power operation. In contrast, our battery-free sensor system [7] fused the near-field energy harvesting system with the far-field data transmission to provide a relative longer read range.

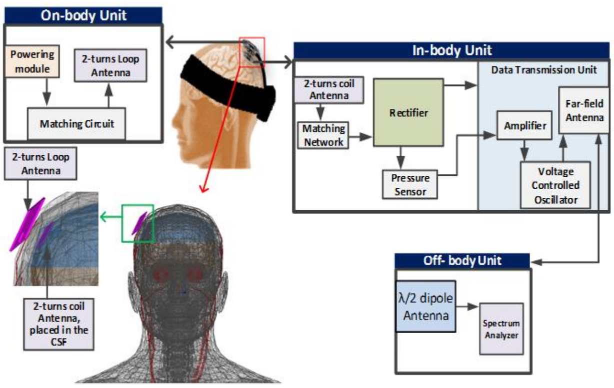


Figure 3. System-level description of the proposed system for wireless ICP monitoring [7].

Fig. 3 shows the system-level architecture of the proposed system. It has three main parts, an implant or in-body unit, on-body unit and off-body unit. In the system, the implant is placed in the subarachnoid space filled with cerebrospinal fluid (CSF). The on-body unit is placed at 5 mm distance from the skin. Total distance between the implant and the on-body unit is 16 mm. Finally, the off-body unit is placed at 1-2 m from the implant. The implant is activated through inductive powering by an on-body unit. After the activation, the implant monitors the pressure through a piezoresistive pressure sensor and transmits it towards the off-body unit at industrial–scientific–medical (ISM) band of 2.45 GHz. The proposed system has two wireless links: near-field and far-field. The near-field link powers the implant and the far-field link transmits the pressure readout outside the skull. In our recent reported results [7], we have successfully activated the implant and monitored the pressure with accuracy of 2 mmHg in a setting mimicking the human head environment.

4. Conclusion

Intracranial implantable devices hold the potential to innovate the treatment of neurological and brain diseases. In this paper, we summarized our ongoing research on two different approaches to achieve far field readable battery-free brain implants.

5. References

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