



## Designing optimised vascular sensors for next-generation health monitoring

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### Abstract

#### Designing Optimised Vascular Sensors for Next-Generation Health Monitoring

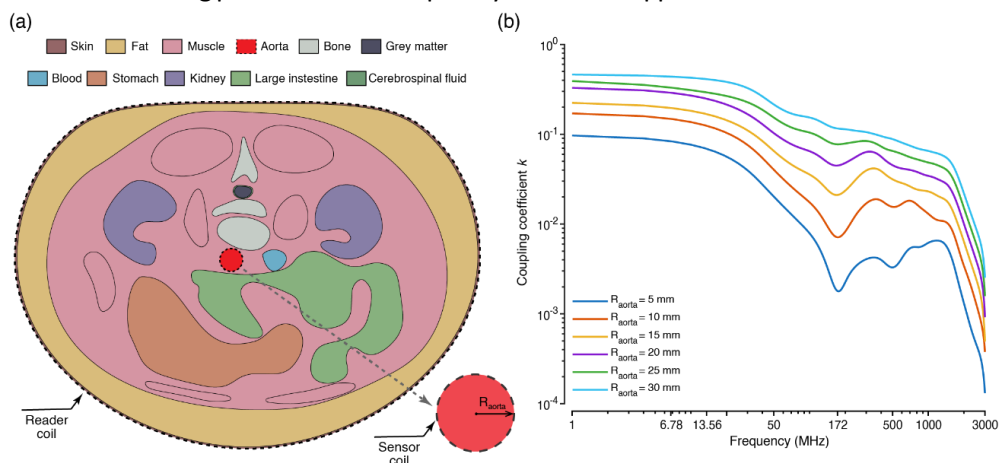
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Implantable bioelectronic sensors enable minimally invasive, continuous monitoring of vital physiological parameters. As an example, magnetic-resonance-based sensors integrated with aortic stent grafts monitor Abdominal Aortic Aneurysm (AAA) progression<sup>1</sup>. The same physical principles also enable Wireless Power Transfer (WPT), allowing simultaneous wireless powering and sensing. However, biological tissues introduce frequency-dependent losses that affect WPT efficiency and sensor performance<sup>2</sup>. This work investigates optimal strategies to mitigate these effects and achieve maximum efficiency in vascular implants, providing physical insights and design guidelines for reliable, long-lasting implantable bioelectronics.

The coupling coefficient  $k$  between the on-body reader coil and the implanted sensor coil defines the power transfer efficiency to AAA sensors. Therefore, the optimum operating frequency of the system is found when  $k$  is maximal, enabling the most efficient wireless power transfer between the reader and the sensor. To determine this optimal frequency, the anatomical cross-section of the human abdominal region (Figure 1a) comprising tissues with frequency-dependent complex permittivities<sup>3</sup> was simulated using COMSOL, across a frequency range of 1 – 3000 MHz, which covers most frequencies used in medical devices. In this model, the reader is a magnetic loop conformal to the skin surface, while the implanted sensor is a loop conformal to the aortic wall (Figure 1a). Then, the self-inductances of the reader  $L_1$  and sensor  $L_2$  along with their mutual inductance  $M$ , are computed, where the coupling coefficient is defined as  $k = M/\sqrt{L_1L_2}$ .

Figure 1b shows that  $k$  increases with the sensor radius due to enhanced magnetic flux linkage. Additionally,  $k$  reaches a maximum and remains nearly constant between 1 and 20 MHz. Then,  $k$  decreases at higher frequencies as a result of increased attenuation in biological tissue, caused by the exponential tissue conductivity increase. Moreover, at low  $k$  values, parasitic capacitance between the coils introduces anti-resonant behaviour, leading to observable dips in the  $k$  curve, most notably at 172 MHz. Finally, considering the frequencies standardised for medical applications<sup>4</sup>, 6.78 MHz and 13.56 MHz are the most suitable, explaining their common use in cardiovascular sensing. Therefore, the sensing system must be designed to operate efficiently below 20 MHz while maximizing  $k$  through carefully selecting sensor and reader coil topologies to achieve reliable power transfer and sensing performance in deep-body biomedical applications.



**Figure 1:** AAA sensing: (a) proposed model and (b) coupling coefficient vs. frequency.

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