

CHAPTER

4

IMPLANTABLE ANTENNA DESIGN CONSIDERATIONS

*Maria Alessandra Sabiniano Florida, Alvir Jamil,
Chua Sheng Chong, and Noor Asmawati Samsuri*

4.1 INTRODUCTION

The design of implantable antennas requires careful attention to size due to limited space within the human body. Miniaturizing antennas are crucial for it to fit within implantable medical devices (IMD), while ensuring it performs effectively and safely. This process involves using various techniques such as adjusting the materials, changing the structure, or adding components to maintain the antenna's functionality despite its smaller size. Apart from size reduction, patient safety must be ensured through ensuring specific absorption rate (SAR) is within safety limits and through enforcement of biocompatibility.

While the miniaturization and biocompatibility of implantable antennas are vital, fabricating them presents additional challenges. Due to implantable antennas possessing a smaller size, inconsistencies occur between designed antenna models and fabricated prototypes. Thus, there are several factors from choice of structure, choice of method, manner of fabrication which must be considered. This chapter discusses important considerations in designing implantable antennas, covering miniaturization, patient safety, biocompatibility, and fabrication.

4.2 MINIATURIZATION

Antenna miniaturization aims to reduce antenna size while retaining functionality. Recent studies on implantable miniaturization focuses on decreasing antenna size in consideration of the limited space available inside IMDs. Various techniques such as material modification, structural tuning, and additional component integration are used to address challenges associated with miniaturization. Methods for antenna miniaturization involve using high permittivity substrates, shorting pins, and meander lines as radiating patches. Furthermore, use of fractal geometries, including the Hilbert curve and Sierpinski triangle, offer an alternative approach to reducing design dimensions while supporting a multiband profile. Although such techniques achieve miniaturization, the complexity of designs and low peak gain limit their suitability for most IMD integration. Upcoming sections discuss miniaturization techniques in further detail.

4.2.1 High Dielectric Substrate

Utilization of high permittivity substrates is a widely adopted approach to reducing antenna size in research applications. High-permittivity substrates cause shift of the resonant frequency towards a lower frequency, thereby shortening operational wavelength. To achieve this effect, several high dielectric materials are used in implantable antennas, such as alumina ceramic (with a relative permittivity, ϵ_r , of 9.4) and Rogers high-frequency substrate materials such as RO3210, RO3010, and RT/Duroid 6002 ($\epsilon_r=10.2$). These materials exhibit a low loss tangent of ($\tan \delta=0.0022$), an almost negligible value, leading to minimized losses within the substrate.

Although high permittivity substrates effectively facilitate antenna miniaturization, extremely high permittivity can convert input power into surface waves, which adversely affect antenna radiation efficiency. Additionally, accounting for the varying dielectric constant of the human tissue is also crucial, since differences in dielectric properties

influence shifts in operational frequency towards higher or lower values during implantation. The relationship of the effective dielectric constant, ϵ_{eff} of the substrate with the resonant frequency, f_r is shown in Equation 4.1, where the resonant frequency depends on the patch dimensions and the substrate's ϵ_{eff} . Thus, high permittivity substrates raise ϵ_{eff} , resulting in resonant frequency decreasing. This enables smaller patch sizes to resonate at the same frequency, ultimately reducing the overall size of antennas.

$$f_r = \frac{c}{2L\sqrt{\epsilon_{\text{eff}}}} \quad (4.1)$$

4.2.2 Pin Shorting Technique

The pin shorting technique inserts a small structure, called a shorting pin to connect the antenna patch to the ground plane. This leads to an increase in the effective size of antennas, enabling physical dimensions to be reduced at the target operating frequency. By using the ground plane in this approach, the effective height of the monopole antenna is increased, producing a planar inverted-F antenna. The resulting antenna exhibits an identical resonant frequency and operational characteristics as an enlarged antenna lacking a shorting pin. However, as shown in Figure 4.1, the inclusion of a shorting pin results in a reduced opening size, thereby lessening directivity which affects the effective amplification of the antenna.

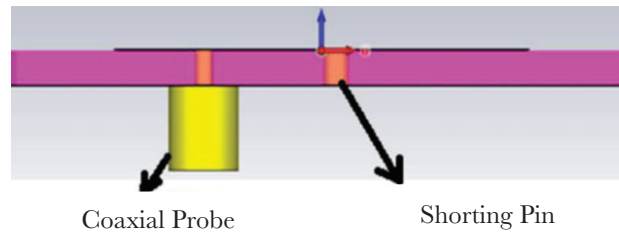


Figure 4.1 Labelled diagram of a shorting pin in an antenna
(Source: Rashid et al., 2018)