

CHAPTER

3

EFFECT OF HUMAN BODY CHARACTERISTICS ON IMPLANTABLE ANTENNA

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3.1 INTRODUCTION

The implantation of an antenna within the human body significantly affects the performance, owing to the complex and unique characteristics of biological tissues. For instance, the diverse tissue composition and dielectric properties, such as permittivity and conductivity, result in the reflection, absorption, and scattering of electromagnetic waves, as shown in Figure 3.1. Permittivity is defined as how an electric field is affected (Taherian & Kausar, 2018). Meanwhile, conductivity is the material's capacity to allow the flow of electric current. Besides that, the tissue density and the presence of different organs with varying properties lead to further attenuation of the signal, affecting performance parameters, such as the radiation pattern, impedance matching, radiated power, bandwidth, and efficiency of the implantable antenna.

Moreover, the body movements and posture changes increase complexity, causing distinct shifts in the performance of the antenna. Therefore, understanding the interaction between biological tissues and

electromagnetic waves is necessary to design implantable antennae that perform appropriately within the human body, given the heterogeneous structure of tissue with fluid composition. Hence, this chapter explores the human tissues' fundamental characteristics, their electrical properties, effect of the human body on antenna properties, and the essential techniques to compensate for the reduction in performance. This understanding facilitates implantable antenna development that satisfies the regulatory standards, ensuring patient safety while maintaining stable wireless communication capabilities for diagnostic, monitoring, and therapeutic applications in medical devices.

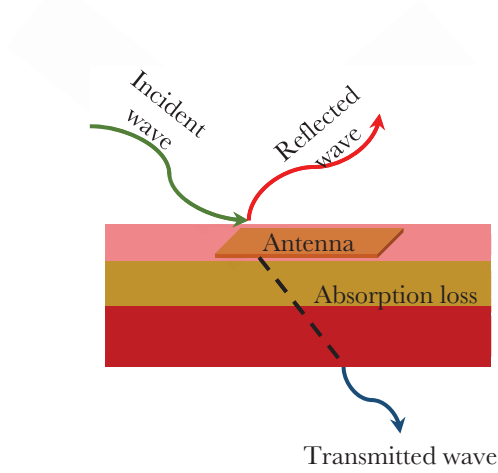


Figure 3.1 Electromagnetic wave integration within the human body

3.2 HUMAN TISSUE STRUCTURE AND ELECTRICAL PROPERTIES

The body is a dynamic and lossy medium with distinct layers of tissue that vary according to the body parts, as depicted in Figure 3.2. Each tissue layer and organ possess distinct electrical properties that vary according to the operating frequencies. These influences coupling of electromagnetic waves with the body. Since implantable antennas must be specifically designed to meet the limitations posed by the biological

environment, a comprehensive understanding of their electrical properties will enable the development of antennas with reliable function within the dynamic human body environment. This subsection presents the discussion of each tissue layer, ranging from skin to bone and the summary of respective dielectric properties, establishing groundwork and references for the upcoming innovations in implantable antenna technology for human well-being.

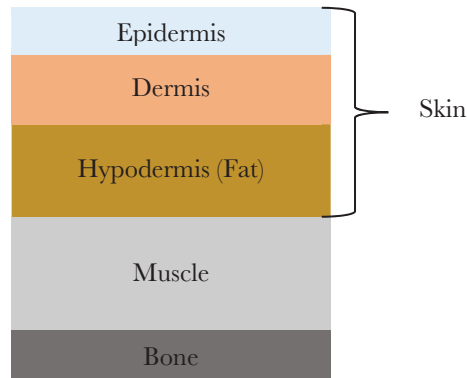


Figure 3.2 Distinct tissue layers of the human body

3.2.1 Skin

Skin is the external layer that serves as a barrier by shielding the internal tissue layers from harmful pathogens or chemicals. The skin layers consist of three layers: Epidermis, dermis, and hypodermis, with varying electrical properties. For instance, the epidermis is the external layer that has relatively low permittivity and conductivity, owing to minimal water content. Conversely, the dermis layer has the highest conductivity and permittivity owing to the presence of electrolytes, water content, connective tissues, and blood vessels. Meanwhile, the hypodermis, known as the subcutaneous fat layer, has the lowest permittivity as it contains higher lipid than water content, which is discussed in the next subsection. Therefore, the varying electrical properties among the skin layers causes signal attenuation.