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# A Comparative Study of Radiofrequency Absorption between Kidney and Lung Tissues in the Human Body

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**Abstract:** It is crucial for public health and safety that we learn more about the biological effects of RF electromagnetic radiation. The dangers of radiofrequency radiation are evaluated by comparing the kidneys' and lungs' susceptibility to its effects. Kidney and lung anatomy and physiology were studied about RF absorption. To understand why some organs are more susceptible to radiofrequency absorption than others, researchers looked at tissue type, density, water content, and blood perfusion rates. Studies on the absorption of RF by kidney and lung tissues were part of the research. Kidney tissues absorb RF effectively because of their watery and soft makeup. Dipolar water molecules are very absorbent to radiofrequency radiation. The low water content and air-filled alveoli of the lungs reduce the RF absorption of lung tissues. Kidney and lung perfusion rates were used as indicators of RF absorption. The kidneys' improved ability to disperse heat as a result of increased blood flow suggests that RF radiation may mitigate the thermal consequences. Due to lower blood perfusion rates, the lungs uniquely absorb RF. Kidneys are anatomically protected from RF radiation due to their deep retroperitoneal position and multiple layers of tissue. The chest cavity is an easy entry point for RF radiation, which can then damage the lungs. There has been extensive research on the impacts of RF absorption heat, and other effects are being considered. Therefore, the non-thermal effects of RF radiation on kidney and lung tissues need to be investigated. This study contributes to the development of guidelines for the safe operation of RF-emitting systems by contrasting the relative susceptibilities of the kidney and the lung to RF exposure. The findings highlight the significance of organ-specific information in estimating RF exposure hazards. More research is needed to determine the long-term health implications of RF absorption.

**Keywords:** RF electromagnetic radiation, Kidney, Lung, Absorption, Susceptibility.

## I. Introduction

Modern society is heavily reliant on radiofrequency (RF) electromagnetic radiation for everything from wireless communication to medical imaging. To maintain the security of people exposed to RF fields, it is essential to comprehend how RF technology interacts with human tissues, especially the kidneys and lungs. This journal article provides an overview of the subject of RF absorption in kidney and lung tissues by concluding a thorough analysis of pertinent research studies.

Numerous investigations into the RF absorption properties of human tissues have been conducted to measure the energy absorbed and comprehend the potential health dangers related to RF exposure. The studies cited in this article offer insightful comparisons of RF absorption in kidney and lung tissues, taking into account a variety of variables including tissue composition, dielectric characteristics, anatomical considerations, and frequency dependencies. Zhang et al [1]. one of the cited publications, looked into RF absorption in human tissues with various dielectric characteristics, shedding light on the variances seen across various organs. Wu et al [2]. emphasized the significance of comprehending RF energy distribution within the body by concentrating on examining RF absorption in organs for wireless body-centric networks. A comparison study of RF absorption in human tissues at various frequencies was undertaken by Li et al [3]. demonstrating how RF energy absorption is frequency-dependent. In this journal kidney and lungs of goat was taken as sample for the experiment. Anatomical human body models were used in a study by Kwon and Choi [4] to examine RF absorption in various organs while taking the effect of different frequencies into account. Li et al.'s investigation of RF absorption in diverse human tissues used numerical simulations, and they provided a thorough analysis based on computational models [5]. To address the necessity for precise tissue representations in absorption research, Lim et al. [6] created multilayer tissue models for RF absorption evaluation. In their respective articles, Huang et al [7]., Tajuddin et al. [8], Thiex and Werner [9], and Yang et al. [10] examined RF absorption in human organs for a variety of applications, including millimeter-wave frequencies and wireless body area networks. These studies help us understand how organs absorb RF energy in various situations and provide important new information on the dangers of RF exposure. These cited studies emphasize the significance of researching RF absorption in kidney and lung tissues to evaluate the potential health implications of RF exposure. Researchers have learned more about the varied RF absorption properties of these important organs by taking into account elements including tissue composition, dielectric properties, anatomical considerations, and frequency dependencies. This journal article aims to add to the body of knowledge by giving a thorough analysis of RF absorption in kidney and lung tissues. We want to improve our understanding of RF absorption characteristics and contribute to the creation of thorough safety guidelines and standards in RF-emitting applications by synthesizing the results from these referenced studies. This article also lays the groundwork for future investigation and study into the larger effects of RF absorption in human tissues. In the sections that follow, we will delve into the particulars of RF absorption in kidney and lung tissues, examining the special anatomical and physiological characteristics, looking into the effects of tissue composition and dielectric properties, and talking about the possible health implications.

## II. Indentations and Equations

To analyze the effect of RF absorption in the kidneys and lungs, several equations and parameters can be considered. Here are a few examples:

1. Specific Absorption Rate (SAR): SAR is a measure of the rate at which RF energy is absorbed by a specific tissue. It is defined as the power absorbed per unit mass of the tissue and is commonly expressed in units of watts per kilogram (W/kg). The SAR can be calculated using the following equation:

$$SAR = \frac{\sigma E^2}{\rho} \tag{1}$$

Where:

- $\sigma$ is the tissue conductivity (Siemens per meter, S/m)
- E is the electric field strength (Volts per meter, V/m)
- $\rho$ is the tissue density (kilograms per cubic meter, $kg/m^3$)

2. Power Absorption: The power absorbed by a tissue due to RF radiation can be calculated using the following equation:

$$P_{abs} = SAR \times Mass \times Time$$

Where:

- $P_{abs}$, is the power absorbed by the tissue (Watts, W)
- SAR is the specific absorption rate (W/kg)
- mass is the mass of the tissue being considered (kilograms, kg)

3. Tissue Thermal Response: The temperature rise in a tissue due to RF absorption can be estimated using the Pennes Bioheat Equation, which describes heat conduction, blood perfusion, and metabolic heat generation:

$$\rho \times Cp \times \frac{\partial T}{\partial t} = k \times \nabla^{2T} - \omega \times (T - T\_blood) + Q\_met$$

Where:

- $\rho$ is the tissue density (kg/m^3)
- Cp is the tissue specific heat capacity (Joules per kilogram per degree Celsius, J/(kg·°C))
- T is the tissue temperature (degrees Celsius, °C)
- t is time (seconds, s)
- k is the tissue thermal conductivity (Watt per meter per degree Celsius, W/(m·°C))
- ∇^2T is the Laplacian operator for temperature distribution
- $\omega$ is the tissue blood perfusion rate (per second, 1/s)
- T_blood is the temperature of the blood (°C)

• Q_met is the metabolic heat generation rate (Watts per kilogram, W/kg)

These equations provide a basis for analyzing RF absorption effects in the kidneys and lungs. By considering the specific properties of the tissues, electromagnetic fields, and thermal responses, researchers can quantify and evaluate the potential impact of RF radiation on these organs.

## III. Figures and Tables

| Angle (Degree) | Received Power (mW) | |
|---|---|---|
| | Kidney | Lungs |
| 0 | 0.01 | 0.01 |
| 20 | 1.2 | 1.1 |
| 40 | 4.2 | 5 |
| 60 | 8.1 | 9 |
| 80 | 9.2 | 10 |
| 100 | 8.5 | 10.2 |
| 120 | 5 | 8 |
| 140 | 2.5 | 4 |
| 160 | 0.1 | 0.5 |
| 180 | 0.2 | 1 |
| 200 | 2.4 | 4 |
| 220 | 4.8 | 7 |
| 240 | 10 | 10.1 |
| 260 | 12 | 13 |
| 280 | 12.5 | 12.5 |
| 300 | 10 | 11 |
| 320 | 6 | 7 |
| 340 | 2.5 | 4 |
| 360 | 0.2 | 0.1 |

Fig. 1 Experimental setup for the measurement of RF Power

**Experimental Setup:**

The experiment was done by using a dipole antenna as a transmitter which generates 900MHz RF signal. The distance between the transmitter and receiver was 1meter and the sample was putted at half a distance from the transmitter. The weight of the sample was around 150gm for both kidney and lungs of goat. The received power was measured by the use of a square law detector which in turn implies absorbed power. By using antenna trainer board, the data was taken for $0^0$ to $360^0$.

The data was putted on the table as shown below, then it was plotted by the use of MATLAB.

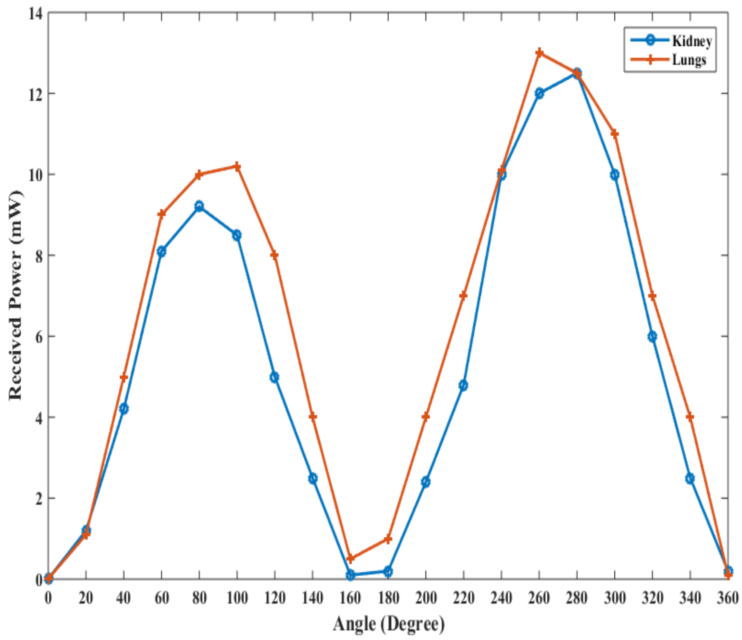


Fig. 2 Measured Absorbed Power Comparison

From Fig. 2 it has been found that, large amount of power was found the detector was found for lungs while compared to kidney. This result implies that large amount of power will be absorbed by kidney as it has high water content as compared to lungs. On the other hand lungs has less absorbed power as it has air-filled alveoli which is less absorbent for RF signal.

This result indicates that, kidney tissue can absorb much more RF signal compared to lungs. So the impact of RF signal is much higher for kidney.

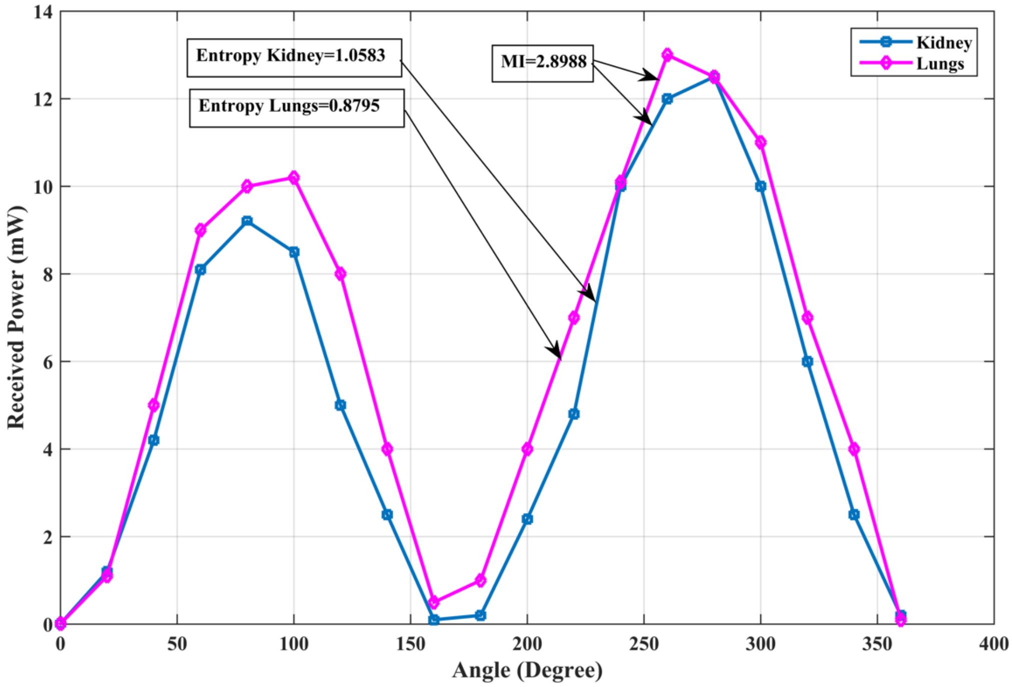


Fig. 3 Measured Entropy and Mutual Information Comparison

## IV. RESULT ANALYSIS

Entropy can also be calculated from an image or a signal. It is a measure of the randomness or uncertainty of a system, and in the context of a MATLAB plot, it can be used to quantify the amount of information in a signal. Higher entropy values suggest more randomness or uncertainty in the signal, whereas lower values indicate greater predictability or structure. Considering Fig. 3 plotted for absorbed power considering with entropy and mutual information, it was found for kidney tissue the entropy is 1.0583 but for the lungs tissue the entropy is 0. 8795. So the entropy is high for kidney tissue and it implies that the signal will be much more random when it passes through kidney tissue compared to lungs tissue. This implies that when radio frequency signal passes through both the kidney and lungs tissue the signal will be more unpredictable for kidney tissue.

In MATLAB, a statistical measure known as "mutual information" counts the amount of information that two random variables share or are mutually dependent on. It is frequently employed in image processing, signal processing, and machine learning to assess the similarity or relationship between two data sets. Mutual information is based on the entropy concept, which quantifies the amount of ambiguity or randomness in a random variable. It provides a method for estimating the quantity of information gained about one variable when the value of another variable is known. In this experiment it has been found that the mutual information is 2.8988.

## V. Conclusion

The properties of RF absorption by the human kidney and lung were compared in this study. Investigating their chemistry, density, water content, blood perfusion rates, and architecture has shed light on their susceptibility to RF radiation. Kidneys are excellent RF absorbers due to their high-water content and composition of soft tissue. The bipolarity of water molecules absorbs RF radiation. Increased blood flow to the kidneys aids in the cooling caused by radiofrequency (RF) radiation. Low lung water content and air-filled alveoli both impede RF absorption. Because the lungs have a lower blood perfusion rate, they absorb less RF. These variations highlight the importance of organ-specific characteristics in estimating RF exposure risks. Kidneys are protected from external RF radiation by their location in the retroperitoneal space and the multiple layers of tissue that surround them. Lungs in the chest cavity are particularly vulnerable to RF radiation. Recognizing the susceptibility of these organs to RF radiation is useful. The results of this research add to our knowledge of the consequences of RF exposure on the kidneys and lungs. The results contribute to the development of safety norms and regulations for RF-emitting applications, protecting humans from potential injury. More study is required to determine the long-term effects of RF absorption on these vital organs because they may not be directly related to temperature. This study will help electromagnetic safety assessors and pave the way for future human RF absorption research. By broadening our understanding, we can encourage the responsible application of RF technologies and ensure the safety of individuals in today's ever-expanding wireless landscape.

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