# NEAR ZONE MICROWAVE EXPOSURE OF A BIOLOGICAL SPHERE

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Abstract.

Power deposited into a spherical model of biological tissues is computed for an exciting axial electric or magnetic dipole at different locations and for different frequencies. It is found that near zone fields may deposit higher power into biological structures than plane waves having the same incident strength.

## Introduction

Either in useful applications of microwaves or in determining safe exposure levels, it is necessary to determine limits on microwave power deposited into a body for a given field strength. Previous estimates were based on incident plane wave assumptions. However, near zone fields arising from a near-by complex source geometry may deposit higher powers into the body than a plane wave source having the same incident strength. This can be attributed to the fact that near zone incident fields will excite the body characteristic modes with different excitation coefficients than a plane wave. Thus resonance absorption may occur if a near zone field can excite modes of higher field distribution inside the body.

A complex source geometry may be decomposed into a set of electric or magnetic dipoles. Therefore, the field distribution inside the body may be evaluated by summing the dipole fields. An upper limit on the power deposited may be obtained from a knowledge of the maximum relative absorption of the body when excited by each dipole.

In this paper we consider a spherical model of biological tissues under the influence of an axial electric or magnetic dipole and determine the power deposited into the sphere for different parameters. The sphere and dipole geometry is shown in Fig. 1.

## Formulation

The transmission and reflection coefficients of the vector spherical modes for the sphere[1] are computed for as many modes as necessary. These coefficients depend on radius a, dielectric constant, and conductivity of the sphere.

The incident field from an axial electric or magnetic dipole a distance D from the sphere (D>a) is expanded into vector spherical modes with origin at the sphere centre. A closed form expression was obtained for these coefficients. A straightforward summation gives the transmitted field in the sphere at any point.

To have an insight into the power distribution within the sphere, it is divided into four equal concentric spherical shells and the power deposited in each part is computed.

## Results

The total power into a sphere of 10 cm radius is plotted in Figs. 2,3, and 4 for dipole distances D=30, 15 and 12 cm respectively.

Because of orthogonality of the vector spherical modes, the power deposited into the sphere P can be written as

$$P = \sum_n |g_n^i|^2 \psi_n^2 \qquad (1)$$

where $g_n^i$ are the expansion coefficients of the incident fields and $\psi_n^2$ is the power deposited into the sphere due to mode n with unit incident coefficient.

It was common to refer the power deposited to an incident power density $E_i^2/Z_o$, a concept that is only appealing for an incident plane wave. For general near zone fields it seems more proper to refer the power deposited to the incident electric energy stored within the body volume in its absence. This incident energy can be written as

$$W = \sum_n |g_n^i|^2 \beta_n^2 \qquad (2)$$

It is clear from Eqs. (1) and (2) that different distributions of $g_n^i$ having the same incident electric energy stored W will give rise to different powers deposited into the sphere. This can be made use of in synthesizing an optimum source for microwave power applications.

The results shown are given for dipoles of unit strength and are not normalized to the incident electric energy stored. When this normalization is made, it is found that the relative power deposited into the sphere (P/W) increases as the dipole gets closer to the sphere and is larger for the magnetic dipole than the electric dipole. The relative power is almost frequency independent in the range 1 to 10 GHz because of the increase in conductivity of biological tissues with frequency.

The power distribution inside the sphere is frequency dependent with lower frequencies showing more even power distribution than higher frequencies.

## References

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Mc Graw-Hill, New York, 1941.

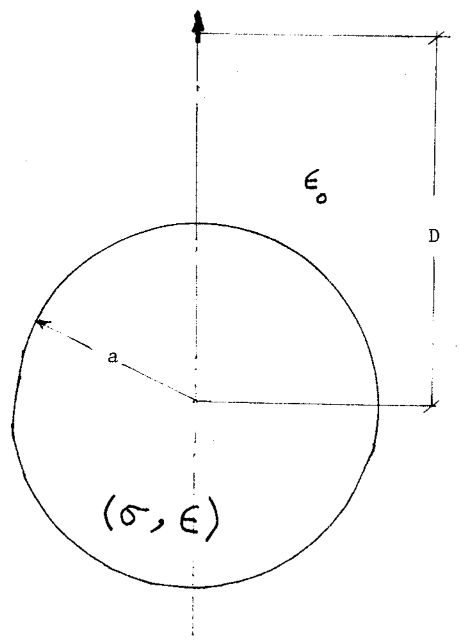


Fig. 1 Geometry of sphere of biological tissues and dipole

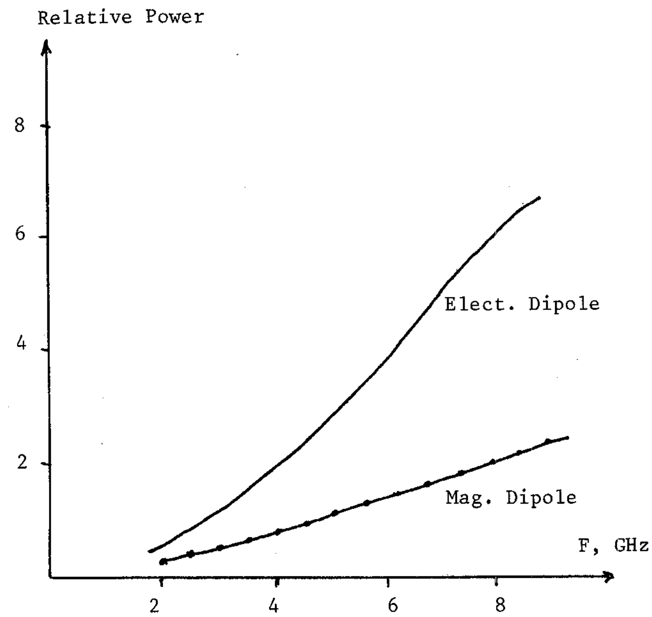


Fig. 2 Power deposited into spherical model, D=30cm

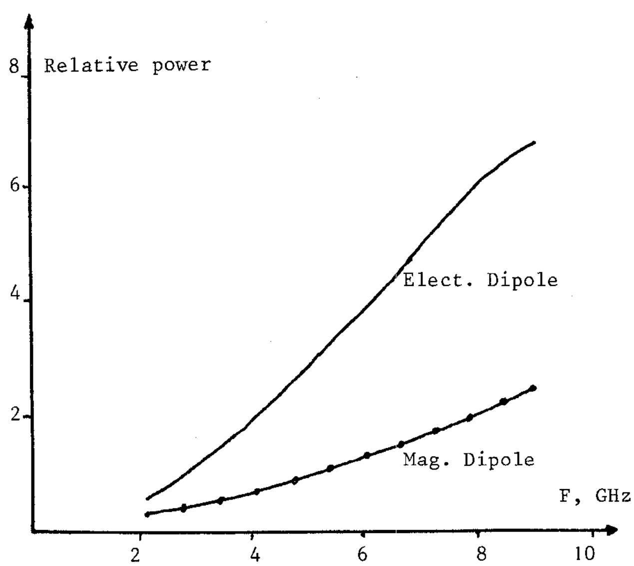


Fig. 3 Power deposited into spherical model, D=15cm

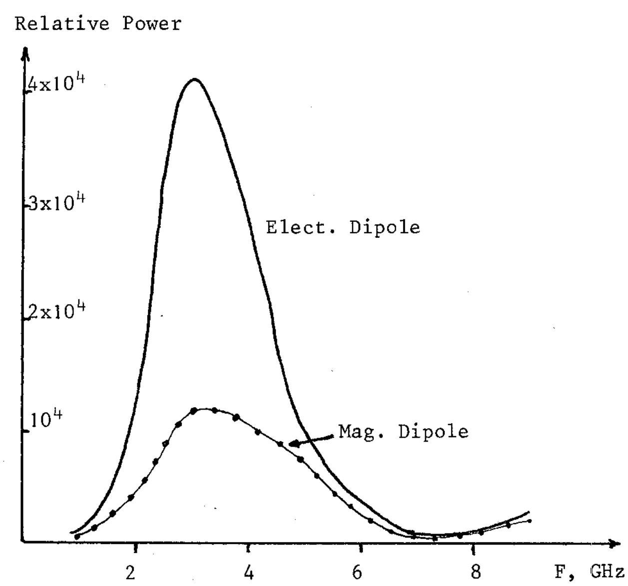


Fig. 4 Power deposited into spherical model, D=12cm