MICROWAVE IRRADIATION DESIGN USING DIELECTRIC LENSES

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Abstract

Theoretical calculations and electric field measurements were made to demonstrate the focusing effect of dielectric spheres (lenses). The results indicate the feasibility of using dielectric lenses for selective partial body irradiation in biological experiments.

The use of dielectric lenses for concentrated partial body irradiation of biological subjects with microwave energy has been reported (1). In the present investigation, theoretical calculations and electric field measurements are made to determine the normalized electric field squared patterns and the focusing factor in a plane behind a plane wave irradiated dielectric sphere. The normalized electric field squared is defined as the electric field squared in the plane ($|\vec{E}|^2$) divided by the electric field squared of the incident plane wave ($|\vec{E}_o|^2$). The focusing factor is the maximum of the normalized electric field squared in the plane.

The formulation for the scattered electromagnetic fields from a plane wave irradiated dielectric sphere has been reported (2). Based on this formulation, a computer program is written to calculate the electric field squared in a plane behind a dielectric sphere. A three dimensional plotting routine is then used to plot the electric field squared in the plane. Fig. 1 shows a plane behind a dielectric sphere irradiated by an electromagnetic plane wave. Fig. 2 shows the electric field squared in a 40 cm x 40 cm plane, 6 cm behind a 20.3 cm diameter polyfoam sphere ($\varepsilon = 1.89$, $\tan \delta = 0.0007$) and perpendicular to the direction of an incident 2450 MHz plane wave. Fig. 3 shows the electric field squared in the same plane behind the same sphere, but irradiated by an incident 10 GHz plane wave. In both cases the beam of focused electric field has an elliptic cross-section with the long side parallel to the direction of the electric field of the incident plane wave ($\vec{E}_o$). The 10 GHz focused beam is narrower and possesses a much higher focusing factor compared to that of the 2450 MHz. The diameter of the dielectric sphere is then varied from 20.3 cm to 40.6 cm. Fig. 4 shows the electric field squared pattern behind a 40.6 cm diameter polyfoam sphere irradiated by a 2450 MHz plane wave. The increased focusing factor due to increased diameter of the sphere is indicated. However, the beam size (cross-sectional area at the base of the focused beam) remains about the same. Calculations are also made for the focusing effect of a polyethylene sphere ($\varepsilon = 2.26$, $\tan \delta = 0.00036$). For the same sphere diameter and source frequency, the focused beam for the polyethylene sphere is similar in shape and size to that of the polyfoam sphere. However, the focusing factor is higher for the polyfoam sphere. Table I shows the focusing factors on the 40 cm x 40 cm plane 6 cm behind the spheres as a function of sphere diameter, source frequency and dielectric material of the sphere. It should be emphasized that the focusing factor depends on the source frequency, size and dielectric properties of the sphere and the distance of the plane behind the sphere. Hence the focusing factor at 6 cm behind a sphere does not necessarily represent the maximum focusing factor that can be realized behind the sphere.

Electric field measurements are made in an anechoic chamber behind a 20.3 cm diameter polyfoam sphere irradiated by 2450 MHz CW microwave radiation from a standard gain horn 150 cm from the sphere. A Narda model 8305 radiation monitor with a model 8323 probe is used for the measurement. Figure 5 shows the comparison between calculated and measured value of the normalized electric field squared in a 20 cm x 20 cm plane, 6 cm behind the polyfoam sphere. The measured and calculated results agree very well except at the peak of the focused beam. The measured focusing factor is 7.0. This slightly lower value compared to the calculated value of 8.5 may be partly due to the averaging effect of the measuring antenna which has a 5 cm diameter.

This investigation indicates that by proper selection of frequency and dielectric lens, focused microwave radiation can be produced for localized exposure of biological subjects. This technique may also be useful for medical applications. Research is needed to determine the tissue penetration characteristics of such a microwave exposure field. To increase the practical utility of the focusing dielectric lens, research may be needed to determine the possibility of replacing the incident plane wave source by an aperture source placed close to the dielectric lens.

References

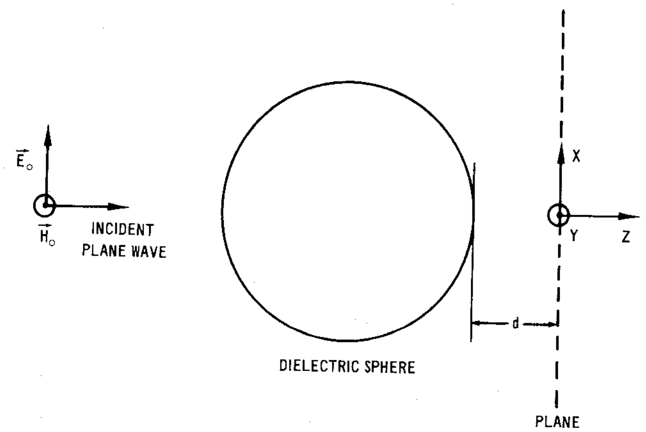
1. R.L. Carpenter, E.S. Ferri and G.J. Hagan, "Use of a dielectric lens for experimental microwave irradiation of the eye," Conference on the Biological Effects of Non-ionizing Radiation. New York, Academy of Sciences, Feb. 12-15, 1974.

2. J.A. Stratton, Electromagnetic Theory. New York: McGraw-Hill, 1941, pp. 563-570.

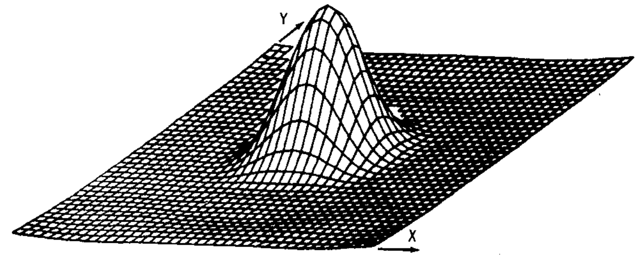
Table 1

Focusing Factor 6 cm behind a Dielectric Sphere

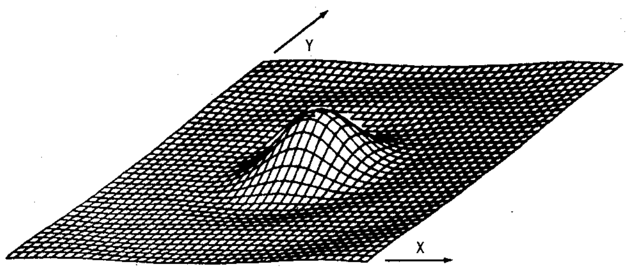
Sphere Diameter (cm)	Focusing Factor			
	2450 MHz		10 GHz	
	polyethylene	polyfoam	polyethylene	polyfoam
20.3	6.7	8.5	16.5	40.1
25.4	9.3	12.3	37.7	72.1
30.5	9.6	14.3	66.9	103.3
35.6	21.0	18.3	89.5	149.7
40.6	22.7	30.2	170.2	158.5



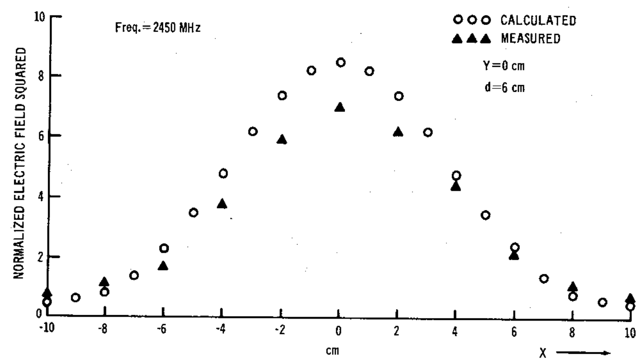
Plane behind a dielectric sphere irradiated by an electromagnetic plane wave. (Figure 1)



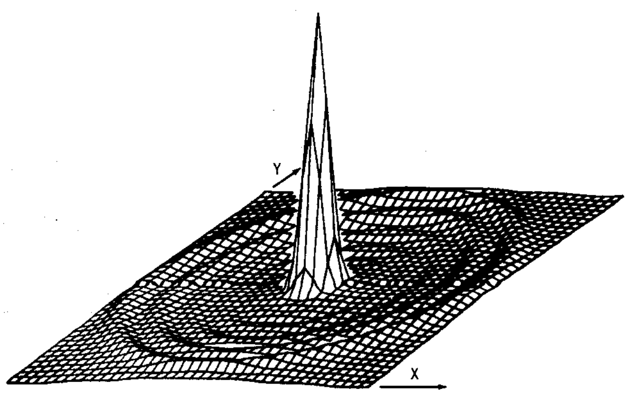
Normalized electric field squared on a 40 cm x 40 cm plane, 6 cm behind a 40.6 cm diameter polyfoam sphere. Frequency = 2450 MHz. Peak = 30.2. (Figure 4)



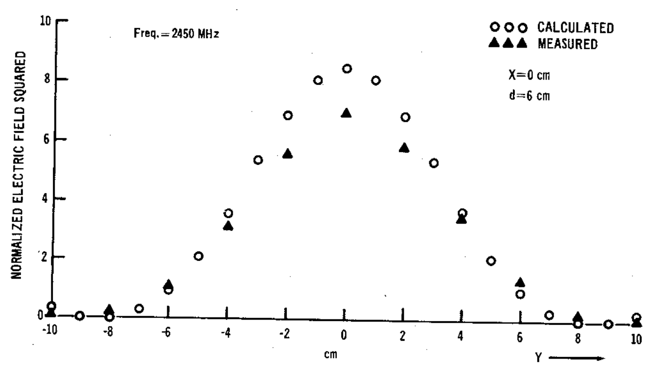
Normalized electric field squared on a 40 cm x 40 cm plane, 6 cm behind a 20.3 cm diameter polyfoam sphere. Frequency = 2450 MHz. Peak = 8.5. (Figure 2)



Comparison of calculated and measured normalized electric field squared on a 20 cm x 20 cm plane, 6 cm behind a polyfoam sphere along the direction of incident electric field vector ($\vec{E}_o$) (Figure 5a)



Normalized electric field squared on a 40 cm x 40 cm plane, 6 cm behind a 20.3 cm diameter polyfoam sphere. Frequency = 10 GHz. Peak = 40.1. (Figure 3)



Comparison of calculated and measured normalized electric field squared on a 20 cm x 20 cm plane, 6 cm behind a polyfoam sphere along the direction of incident magnetic field vector ($\vec{H}_o$). (Figure 5b)