we start with the observation that h_d is a gradient:

$$h_d = \nabla\phi_d. \tag{B2}$$

Then from the divergence theorem

$$\int_\Omega (m + h) \cdot h_d \, dV = \int_{S_\Omega} \phi_d(m + h) \cdot dS - \int_\Omega \phi_d \nabla \cdot (m + h) \, dV. \tag{B3}$$

The first integral on the right-hand side is zero because the RF magnetic induction $(m + h)$ must be parallel to the coupling conductors, which define the surface S_Ω. The second integral is zero because $\nabla \cdot (m + h) = 0$.

A similar argument demonstrates that

$$\int_\Omega h_e \cdot h_d \, dV = 0. \tag{B4}$$

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Further Studies on the Microwave Auditory Effect

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Abstract—**Auditory signals generated in humans and animals who are irradiated with short rectangular pulses of microwave energy have been studied. Assuming that the effect arises from sound waves generated in the tissues of the head by rapid thermal expansion caused by microwave absorption, and using a technique described previously, the governing equations are solved for a homogeneous spherical model of the head under constrained-surface conditions. The results indicate that the frequency of the auditory signal is a function of the size and acoustic property of the head only. While the amplitude and frequency of the microwave-induced sound are higher than those predicted by the stress-free boundary condition formulation, they are compatible with the experimental results reported to date.**

INTRODUCTION

IN RECENT YEARS many investigators have studied the auditory sensations produced in man by appropriately modulated microwave energy [1]–[5]. Other investigators [3], [5]–[7] have shown that electrophysiologic auditory activity may be evoked by irradiating the brains of laboratory animals with rectangular pulses of microwave energy. Responses elicited in cats both by conventional acoustic stimuli and by pulsed microwaves were similar and they disappeared following disablement of the cochlea and following death. More recently, cochlear microphonics have been recorded from the round window of cats and guinea pigs during irradiation by pulse-modulated 918-MHz microwaves. These results suggested that microwave-induced auditory sensation is transduced by a mechanism similar to that responsible for conventional sound perception and that the primary site of interaction resides somewhere peripheral to the cochlea. A peripheral response to microwave pulses should involve mechanical displacement of the tissues of the head with resultant dynamic effects on the cochlea.

Several physical mechanisms have been suggested to account for the conversion of microwaves to acoustic energies; these include radiation pressure, electrostriction, and thermal expansion [3], [8]–[10]. A comparison of these three mechanisms for planar geometries revealed that the forces of

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