$$\sigma_f = 4\mu\, u_0 S t_0 + \sum_{m=1}^{\infty} A_m k_m M_m [(\sin\omega_m t)/\omega_m - \sin\omega_m (t-t_0)/\omega_m], \quad t \geq t_0 \tag{5}$$

where

$$u_0 = (I_0/\rho c_h)[\beta/(\lambda + 2\mu)] \tag{6}$$

$$Q = (a/N\pi) j_1(N\pi r/a) \pm [4\mu/(3\lambda + 2\mu)]\,[r/(N\pi)^2] \tag{7}$$

$$S = \pm (1/N\pi)^2 - j_1(N\pi r/a)\,/\,(N\pi r/a) \tag{8}$$

$$M_m = [(\lambda + 2\mu) j_0(k_m r) - 4\mu j_1(k_m r)/(k_m r)] \tag{9}$$

and

$$A_m = \mp 2u_0 a/(N\pi)^2 \,\{[4\mu/(3\lambda + 2\mu)]\,[j_2(k_m a)/(k_m a) - k_m a j_0(k_m a)/[(k_m a)^2 - (N\pi)^2]]\}/\{[j_1(k_m a)]^2 - j_0(k_m a) j_2(k_m a)\} \tag{10}$$

for $k_m a = m\pi$. In cases where $m\pi = N\pi$, equation (10) reduces to

$$A_m = -u_0 a/(N\pi)\,[1 + 24u/(3\lambda + 2\mu)(1/N\pi)^2] \tag{11}$$

The upper sign in equations (7) to (10) and in subsequent expressions denotes $N = 1, 3, 5, \ldots$ and the lower sign denotes $N = 2, 4, 6, \ldots$

The fundamental frequency of sound generated in a spherical head with constrained boundary but without shear stress was shown to be given by

$$f_{1c} = 4.49\, c_1/(2\pi a) \tag{12}$$

which is higher than that predicted by equation (1) under stress-free conditions. The radial displacement for constrained surfaces is given by

$$u = u_0 D t + \sum_{m=1}^{\infty} A_m j_1(k_m r)(\sin\omega_m t/\omega_m), \quad 0 < t < t_0 \tag{13}$$

$$u = u_0 D t_0 + \sum_{m=1}^{\infty} A_m j_1(k_m r)[\sin\omega_m t/\omega_m - \sin\omega_m (t - t_0)/\omega_m], \quad t > t_0 \tag{14}$$

and the pressure is

$$\sigma = u_0 G t + \sum_{m=1}^{\infty} A_m k_m H_m (\sin\omega_m t/\omega_m), \quad 0 < t < t_0 \tag{15}$$

$$\sigma = u_0 G t_0 + \sum_{m=1}^{\infty} A_m k_m H_m [\sin\omega_m t/\omega_m - \sin\omega_m (t - t_0)/\omega_m], \quad t > t_0 \tag{16}$$

where

$$D = (1/N\pi)[a j_1(N\pi r/a) \mp (r/N\pi)], \tag{17}$$

$$G = -(4\mu a/N\pi r) j_1(N\pi r/a) \mp (1/N\pi)^2 (3\lambda + 2\mu) \tag{18}$$

$$H_m = (\lambda + 2\mu) j_0(k_m r) - (4\mu/k_m r) j_1(k_m r) \tag{19}$$

$$A_m = \pm 2u_0 a (1/N\pi)^2 \,\{(1/k_m a) j_2(k_m a) \pm k_m a j_0(k_m a)/[(k_m a)^2 - (N\pi)^2]\}/\{[j_1(k_m a)]^2 - j_0(k_m a) j_2(k_m a)\} \tag{20}$$

In the following section, equations (1) through (20) are applied to obtain detailed numerical results for the frequency, displacement and sound pressure generated in the heads of guinea pigs and cats exposed to 2450-MHz radiation and in the heads of infants and adult human beings exposed to 918-MHz radiation. The necessary thermoelastic parameters of brain material are given in Table 1. Note that μ is very small compared to λ.

3. NUMERICAL RESULTS

3.1. *Frequency.*

It is observed readily from equations (1) and (12) that the frequency of sound is a function only of the head and of brain tissue acoustic properties. It does not depend at all on characteristics of microwave absorption. Clearly, the acoustic pitch perceived by a given subject will be the same regardless of the frequency of the impinging microwave radiation.

A comparison of fundamental frequency as a function of radius is shown in Figure 1. It is seen that the frequency varies inversely with radius; the smaller the radius, the higher the frequency. Note that the fundamental frequency predicted by the constrained-surface formulation is about 70% higher than that computed from the stress-free expression. Since the head is not perfectly spherical and the surface may best be described as semirigid, it is possible that the actual curve of the fundamental frequency of sound resides somewhere between the two curves that are shown in Figure 1.

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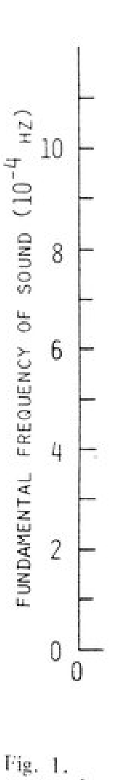

Fig. 1.
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