[2]. But we have found that the asymmetric interaction is not sensitive to the change of the magnetic field.

IV. Conclusion

First-order Bragg interaction in a gyromagnetic-dielectric waveguide is analyzed by a singular perturbation procedure. The expression for the dispersion relation in the vicinity of the Bragg frequency is derived. The Bragg reflection characteristics are shown numerically. It is found that the stop bandwidth and maximum decay of waves due to Bragg interaction can be controlled by the magnetic field.

The result given in the present paper may be useful designing millimeter-wave devices such as tunable filters and electrically scannable leaky wave antenna [9].

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Microwave Pulse-Induced Acoustic Resonances in Spherical Head Models

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Abstract—**Microwave-induced acoustic pressures in spherical models of human and animal heads are measured using a small hydrophone transducer. The measured acoustic frequencies that correspond to mechanical resonance of the head model agree with those predicted by the thermoelastic theory of interaction. Further, a three-pulse burst applied at appropriate pulse repetition frequencies could effectively drive the model to respond in such a manner that the microwave-induced pressure amplitude would increase by threefold or more.**

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I. Introduction

Auditory responses are evoked in human beings and laboratory animals irradiated with rectangular-pulse, modulated microwave energy [1]–[3]. Most investigators of this phenomena believe that the response stems from microwave-induced thermoelastic expansion [4]–[8], i.e., when microwave radiation impinges on the head, a portion of the absorbed energy is converted into heat which produces a miniscule but rapid rise of temperature in the tissues of the head. This rise of temperature ($\sim 10^{-6}$ °C) occurring in a very short time (10 μs) generates rapid thermoelastic expansion of the brain matter or other tissues in the head which then launches an acoustic wave of pressure that is detected by the hair cells in the cochlea [9].

This thermoelastic theory which covers many experimental observations [8]–[10], suggests among other characteristics that the frequency of the auditory signal is a function of the size and acoustic property of tissues in the head [11]–[12]. Specifically, the fundamental frequency of sound was found to be given by

$$f_s = 3.14\nu/(3\pi a) \tag{1}$$

for stress-free surfaces [11]. Thus, the microwave-induced sound is a function of sound propagation speed (ν), and the radius (a) or circumference ($2\pi a$) of the head. To date, experimental support for this observation comes primarily from measured cochlear microphonics in cats and guinea pigs [10], [13], [14], and the well-documented requirement for human preception of pulsed microwaves; i.e., the ability to hear high-frequency sound [1]–[3]. However, direct experimental confirmation for the mechanical resonances inside the head has yet to appear in the literature. This paper presents direct hydrophone measures of pulsed microwave-induced acoustic signals in variously sized spherical head models filled with brain-equivalent materials.

II. Methods and Materials

A. Models

The spherical models were composed of hemispherical voids carefully machined in 20.3×20.3×7.6-cm blocks of foamed polystyrene and filled with brain-equivalent materials. The foamed polystyrene provided a stress-free boundary to the brain model. The electromagnetic, mechanical, and thermal properties of the brain-equivalent material are similar to brain tissues. It is made from gelling agent, finely granulated polyethylene powder, sodium chloride and water [15]. It has a sonic propagation speed of 1600 m/s at room temperature [16]. Typically, two-kilogram batches of the brain-equivalent material were prepared and then evacuated for approximately 30 min to remove included air.

B. Hydrophone Transducer

A spherical hydrophone, 1 cm in diameter, was used in all experiments (Edo Western Inc., Model 6600). The barium titanate piezoelectric element had a response of 50.1 pA/mV for the range of frequencies encountered in this study. The hydrophone was placed in the center of the model. Its output signal was displayed on an oscilloscope and photographed on Polaroid film.

C. Microwave Irradiation Procedure

Pulsed microwave energy at 1.10 GHz and 4-kW peak power was obtained from an Epsco PG5KB generator. The microwave

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