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投　稿

Resonant Absorption of Electromagnetic Waves: Hazard Assessments of Handy Phones and Unusual Animal Behavior before Earthquakes

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電磁波の共鳴吸収：携帯電話の危険性評価と地震前の動物異常行動

論文要旨：　マックスエルの方程式を解いて消滅とミー散乱の断面積の差を計算し、半径がａで抵抗率　r = 0.2 Wm の海水球による吸収断面積を求めた。面積 pa^2 で規格化した断面積は、1 GHzではa = 5 cm で0.8 になり 50 − 60 Hzでは10^{-27}と小さな値である。このことは携帯電話の電磁波の害は問題になるが、電力線では電磁波吸収がないことを示唆している。周波数300ＭＨｚで電力５W/m^2の電磁波をアルビノラットに被曝させる予備実験では、脳内物質のノルアドレナリンの増加とセロトニンの減少を示した。地震の前に小動物から大きな動物へと異常行動が移っていくのは、高周波から低周波へと移る地震の電磁波の共鳴吸収のためと結論した。捕食や情報伝達に電場を用いている電気受容器のある水生動物と同じように、陸上の動物も電磁波電場を感じてもよい。

The difference of the cross sections for extinction and for the Mie scattering of electromagnetic (EM) waves was calculated by solving Maxwell equations to obtain the absorption cross section by a sphere of sea water with radius a and resistivity, $\rho = 0.2$ Ωm. The absorption cross section normalized by πa^2, for $a = 5$ cm is 0.8 at 1 GHz but as small as 10^{-27} at 50 - 60 Hz, suggesting hazardous effect for handy phones, but not for power line cables. A preliminary exposure of EM waves at 300 MHz and about 5 W/m^2 to albino rats indicated the enhanced noradrenaline and reduced selotonin. The retrospective reports of unusual animal behavior before earthquakes from early small to later large animals was ascribed to resonant absorption of seismic EM waves from high to low frequencies. Land animals might detect the electric field of EM waves as aquatic animals with electrosensory organs used to capture preys and to communicate with each other.

KEYWORDS: Electromagnetic wave, frequency, hazard, earthquake, rat, resonance, handy phone, morphic resonance

1. Introduction

Ordinary people are exposed to electromagnetic (EM) waves in a wide range of frequency daily in modern society. Some have psychogenic anxiety to invisible EM waves like to ghosts and devils. Seismic electric field generated from the epicenter has recently been ascribed to the cause of retrospectively reported unusual animal behavior before earthquakes[1] rather than charged aerosols.[2] This might cause unnecessary concern over hazardous effect of EM waves since a slightly high probability of childhood cancer[3] was reported for residents living close to cables of electric power lines. Effects of EM waves and electric and magnetic fields are still controversial among specialists.[4, 5]

Biological effect of microwaves were studied back in 1970's whether some animals can hear microwaves in the conference of seismic unusual animal behavior.[4] We studied behavioral responses of animals to the applied electric field pulses and EM waves in the context that retrospectively reported unusual animal behavior is due to stimuli of pulsed electric fields.[1] Most of mysterious phenomena on precursors statements by public and mass media can be reproduced in experiments and elucidated as electromagnetic phenomena. [1] An EM model of fault behavior indicates that a pulsed field appear at a fault zone. [7]

In this letter, an absorption cross section of EM waves for a salt water sphere has been calculated as a phantom of animals by solving Maxwell's equations as for the Mie scattering of light by colloids [8-11] and voids.[11,12] A resonance absorption depending on the object size is discussed for elucidation of unusual animal behavior and hazards of EM waves. The enhancement of noradrenaline in the bloods of rats by exposure of EM waves is presented as a preliminary work made in collaboration with verterinary physiologists.

2. Experimental

A rectangular antenna with the length of 0.3 m x 0.3 m was fabricated with copper pipes of 1/4 inch. Output from a microwave signal generator (Advantest.,10 MHz - 18 GHz , 0 - 10dBm) at about 100 - 300 MHz was amplified using a power amplifier (Thamway T142-4029A, 40dB) . A frequency of 300 NHz was selected to give a maximum voltage standing wave ratio (VSWR) for this antenna-amplifier system. The antenna was placed at around the bottom level of the free moving unit for a rat as shown in Fig 1. The power at the center of free moving unit where an albino rat was exposed to near field EM waves for one hour was monitored by a EM radiation meter (EMR-20, Wandel & Goltermann). The power level was about 5 W/m^2 or about 50 V/m.

The in-vivo brain microdialysis was performed under a free-moving condition[12] as in Fig. 1. The ventromedial hypothalamus (VMH), which is a rostral center of the sympathetic nervous system, was perfused with the artificial cerebrospinal fluid (NaCl 147 mM, $CaCl_2$ 2.3 mM, KCl 4 mM, pH 5.9 - 6.0) at 1.0 microliter per minute using a microinfusion pump (CMA 100, Carnegie Medicine, Stockholm, Sweden). Perfusate was collected into Eppendorf tubes kept on ice and was immediately measured by a high precision liquid chromatography (HPLC) system. Blood samples were taken for the measurements of noradrenaline and adrenaline before and after exposure to EM waves from precannulated conscious male Sprague-Dawley rats (Kiwa Laboratories, Wakayama, Japan), 250 - 350 g in weight. Statistical analysis was performed by multifactor analysis of variance (ANOVA) and Duncan's multiple range test conventionally used in the stress analysis. [13] Significance level, p was set at $p = 0.05$. Details of microdialysis study on modification of hypothalamic neurotransmitters in streptozotocin-diabetic rats are described elsewhere.[13]

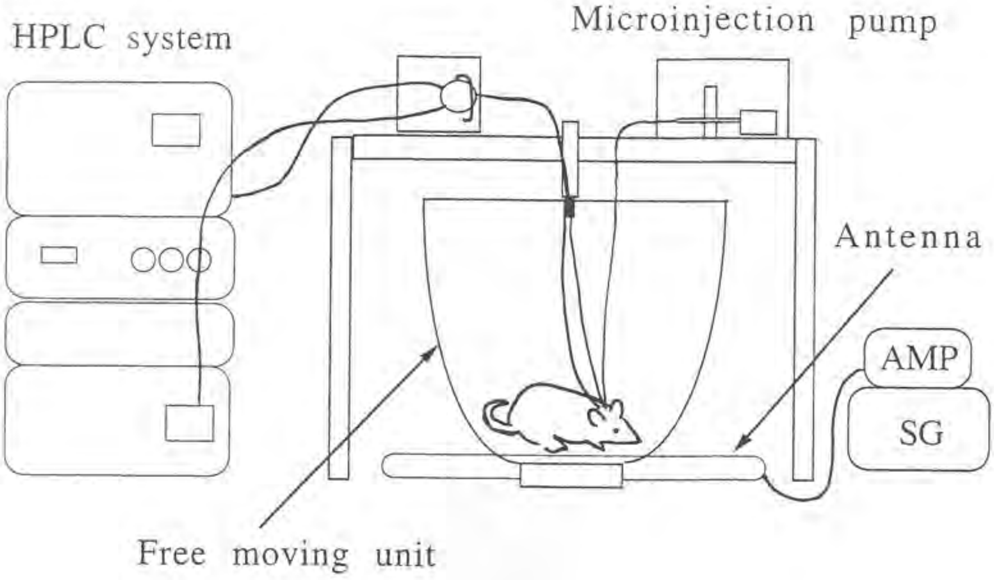


Fig. 1. An overview of the experiment on the exposure of electromagnetic (EM) waves from the antenna to rats. Blood and dialysate samples were taken from conscious rats under a physiological condition, and immediately measured by a high precision liquid chromatography (HPLC) system.

3. Theoretical and Experimental Results

3.1 *Theory of resonant absorption cross section for a dielectric sphere*

The absorption rather than the Mie scattering[8-12] was calculated by solving Maxwell's equations for a sphere of salt water of radius a and resistivity ρ as schematically shown in Fig.2. A dimensionless parameter q of $q = \frac{2\pi a}{\lambda}$, was introduced, where λ is the wavelength of incident EM waves in vacuum. The cross section for extinction of EM waves, Q_{ext} was expressed using Bessel functions in the cylindrical coordinate, $J_{l+1/2}(r)$ and $Y_{l+1/2}(r)$ in forms of $\psi_l(r) = \sqrt{\frac{\pi}{2}} J_{l+\frac{1}{2}}(r)$ and $\chi_l(r) = -\sqrt{\frac{\pi}{2}} Y_{l+\frac{1}{2}}(r)$ for an integer, l as follows.

$$Q_{ext} = \frac{2}{q^2}(2l+1)\,\mathrm{Re}[a_n + b_n] \qquad (1)$$

where a_s and b_s are given using $\zeta_l(r) = \psi_l(r) + i\chi_l(r)$ for simplicity as

$$a_n = \frac{\psi_l'(mq)\psi_l(q) - m\psi_l(mq)\psi_l'(q)}{\psi_l'(mq)\zeta_l(q) - m\psi_l(mq)\zeta_l'(q)} \, , \qquad (2)$$

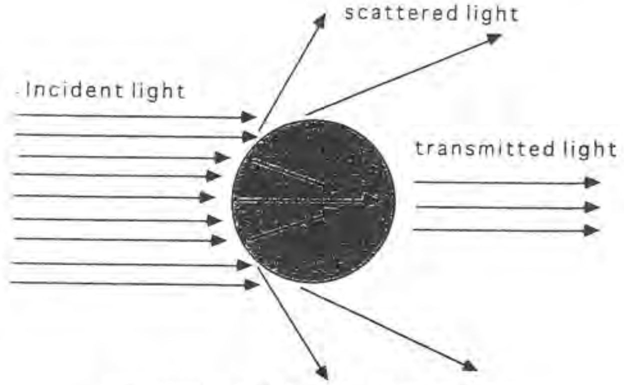
$$b_n = \frac{m\psi_l'(mq)\psi_l(q) - \psi_l(mq)\psi_l'(q)}{m\psi_l'(mq)\zeta_l(q) - \psi_l(mq)\zeta_l'(q)} \, . \qquad (3)$$

The scattering cross section known as the Mie scattering is given by

$$Q_{sca} = \frac{2}{q^2}(2l+1)\left(|a_n|^2 + |b_n|^2\right) \quad (4)$$

The absorption cross section, Q_{ab} is given as a difference, $Q_{ab} = Q_{ext} - Q_{sca}$.[8]

The "absorption cross section ratio" normalized by the real cross section of πa^2, $Q_{ab}/\pi a^2$ was calculated at three typical frequencies of 1 GHz, 316 MHz and 100 MHz using dielectric constant of salt water at different frequencies[8,9] as given in Fig. 3 . The ratio has a peak at the frequency where $2\pi a = m\lambda_o$ for an integer m and $\lambda_o = c/f$, the wavelength in vacuum and is about 0.8 for the resonant absorption at 1 GHz, but negligibly small as 10^{-27} at 50- 60 Hz .



Absorption = Extinction - Scattering

Fig.2. The absorption of electromagnetic waves by a sphere with radius a , dielectric constant ε and resistivity ρ as a difference of the extinction and the Mie scattering.

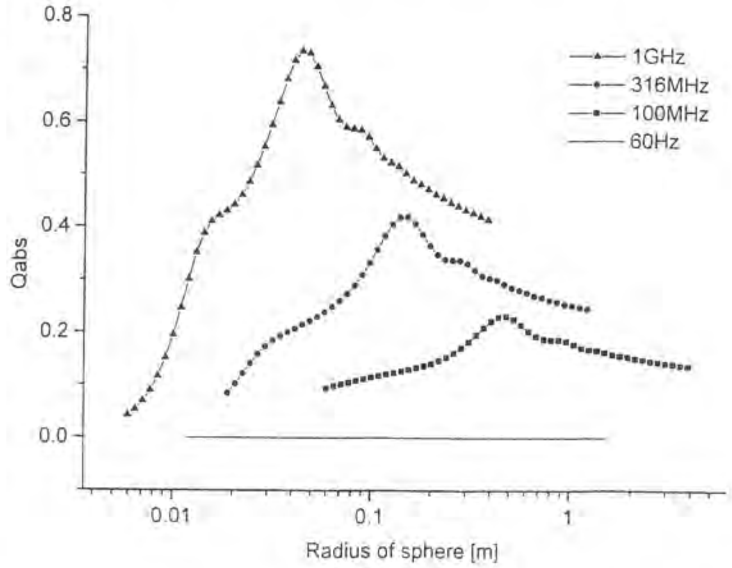


Fig. 3. The absorption cross section of EM waves relative to the real cross section of πa^2 as a function of the for 1 GHz, 316 MHz and 100 MHz. The ratio for EM waves radius a at 50 and 60 Hz is of the order of 10^{-27} .

3.2 *Preliminary experiments on EM Exposure to albino rats*

The sleeping rat waked and stand up upon exposure of EM waves. Rats looked to keep vigil soon after the exposure. The characteristic behavior of grooming and washing face was observed as in the experiment of electric field effects.[1] A typical effect of exposure on plasma concentration of noradrenaline and adrenaline are shown in Fig. 4. Noradrenaline levels, an appropriate indicator of a state of excitement, were significantly increased during and even after exposure to EM waves. However, adrenaline levels were definitely decreased. Plasma adrenaline is released from the adrenal medulla, via a stimulation of the sympathetic nervous system and an index of uneasiness.

Hypothalamic concentration of noradrenaline, serotonin, and γ-aminobutyric acid (GABA) were fluctuated by exposure to EM waves as shown in Fig. 5. The changes in hypothalamic noradrenaline and GABA might be connected with those in plasma noradrenaline as was discussed previously[13]. These experiments indicate that EM waves at 300 MHz affect the metabolism.

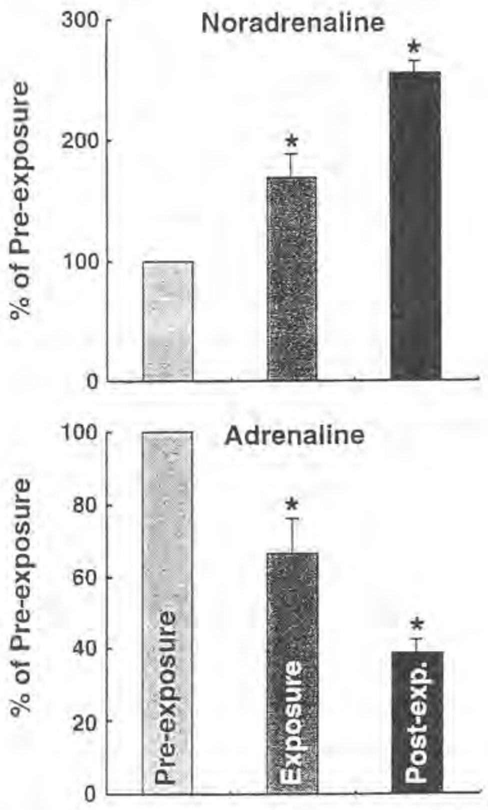


Fig. 4. Plasma levels of noradrenaline and adrenaline for blood samples out of rats for exposure of 90 min for three samplings: pre-exposure, 10 min after the start of exposure to EM waves (exposure) and 10 min after the end of exposure (post-exp.). Percent age of pre-exposure level are indicated with the mean standard errors (MSE) of 3 - 4 animals.

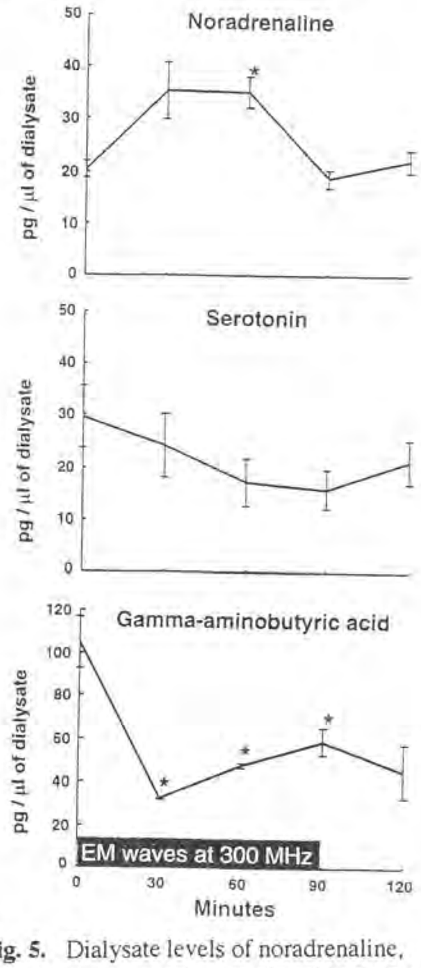


Fig. 5. Dialysate levels of noradrenaline, serotonin, γ-aminobutyric acid (GABA) in the hypothalamic microdialysis study. Values are the mean standard (SE) of 3 - 4 animals.

4. Discussion

4.1 *Energy absorption by rat*

Noradrenaline levels as an indicator of excitement were increased during and even after exposure to EM waves, but adrenaline levels, by contrast, were decreased. Plasma adrenaline is an index of uneasiness and was released from the adrenal medulla, via a stimulation of the sympathetic nervous system. These responses are neither observed under a normal condition nor a stress suggesting some chaos in animals. Rats must have behaved silently and resisted the EM waves. Consequently, it is likely that the exposure made animals disorderly in physiological regulation systems.

We have studied several literatures on the biological effect of microwaves.[4] Most of the works does not take the relation between the size of animals and the resonant frequency into account.[6] The observed effects on rats at a frequency are naturally not observable for monkeys and vise versa. Exposure of EM waves at 2.4 GHz suggest a resonance for a diameter $2a$ = 2.5 cm. If the size of rats is twice more, the cross section decreases considerably and the same result will not be reproduced. Evolution of rat brain tumors may not occur.

The situation will be more complicated in reality, since the body is surrounded by a dry skin electrically resistive. However, this simple calculation may still be of use to explain the resonant effect of biological hazard semiquantitatively. Preliminary experiment on rats are remarkable though detailed studies on more animals and statistical evaluation are needed. We notify physiologists to consider this morphic resonant effect equivalent to impedance matching of EM waves.

4.2 *Power-lines at 60 Hz and handy phone at 0.8 GHz*

The safety regulation of the magnetic field intensity,[3] B = 0.5 mT for general public correspond to $F = cB = 1.5 \times 10^5$ V/m and Poynting vector of EM waves, $S = F^2/2Z = 2.8 \times 10^7$ W/m^2, where Z is the characteristic impedance giving $Z = 377\ \Omega$. Hence, the absorption energy, S_{abs} obtained by multiplying the cross section ratio at 50 and 60 Hz, $S_{abs} = 10^{-27}S = 2\text{x}10^{-20}$ W/m^2 is negligible for a human surface area of 1 m^2 and metabolism of about 100 W. Hazardous effect of EM waves from power lines may be negligible so far as the resonant absorption is concerned: the effect of static electric and magnetic field is out of the scope of the present work.

The regulation of 0.5 mT for power lines should not be extended to the handy phone at 0.5 - 1 GHz, where $Q_{ab}/\pi a^2$ is close to 0.1 - 1.0. The energy $S = 2.75 \times 10^7$ W/m^2 (B = 0.5 mT) at 0.5 GHz would be almost fully absorbed at a frequency where the wavelength and the size of an object is comparable. The effective impedance is small to induce the current and so the EM energy is efficiently dissipated in a body. Practically, handy phones and PHS at 0.5 - 1 GHz emit power of 2 W and 80 mW, respectively leading to respective power density of 64 W/m^2 and 2.5 W/m^2 at a distance of 5 cm ($4\pi r^2 = 0.0314$ m^2). The internal field would be about 2 V/m and 0.012 V/m for $Q_{ab}/\pi a^2 = 1$ and $\varepsilon^* = 80$. These would still not be noticed by an ordinary human beings, but noticed by sea lions and some sensitive fish with electrosensory organs.[1, 15]

Hazardous effect of handy phones must be considered from preliminary results on rats. Hot spots might be induced by EM waves in an inhomogeneous body, but the absorbed energy may be dissipated by blood flow. A simple theory and preliminary experiments may not be sufficient to evaluate the biological effect. We only address to physiologists that the resonant absorption of EM energy must be considered taking both the size of animals and the frequency into account. If the hazardous effect like brain tumor evolution of human beings with a head diameter d_{human} is to be experimented using rats with a head diameter d_{rat}, the frequency of exposed EM waves must be multiplied by d_{human}/d_{rat}. The resonant frequency is around 2.5 GHz for a head of rats with $2a = 3$ cm and around 0.6 - 1 GHz for a human head ($2a$ = 10 - 15 cm).

Table 1. Regulation and recommendation of the maximum power densities of electromagnetic (EM) waves and their cross section ratio for absorption with the absorption power densities by a saline water sphere with a radius 5 cm. Some biological effects of microwaves reported in literatures are also given for comparison together with the calculated energies for handy phones.

Frequency	Magnetic field B (mT)	Power density S (W/m^2)	ratio Q	Absorbed power S_{ab} (W/m^2)	Field * F_{in} (V/m)	Comment
Regulations						
50-60 Hz	0.5 mT	2.75×10^7	10^{-27}	2.75×10^{-20}	3.4×10^{-22}	NE
1 GHz	0.5 mT*	2.75×10^7	0.8	2.2×10^7	1.1×10^2	Hazardous ?
1 GHz	1.0 μT	2.25×10^2	0.8	1.8×10^2	2.0	Marginal**
Microwave	-----	50 (USA)	0.1?	5?	0.55	
(3 - 10 GHz)		0.5 (USSR)	0.1?	0.05	0.055	
Experiment on animals						
rats 1 GHz	(pulse enhanced)	7	0.7	5	50	
	(circadian rhythms)	64	0.8	50	2	
rabbit	(eye)	1,500	0.5	750		
Assessment of handy phones						
1GHz HP	(2 W)	16 ***	0.8 ?	12.8	35.0	Hazardous ?
1GHz PHS	(80 mW)	0.64 ***	0.8 ?	0.5	14.3	Marginal ?

* Electric field of EM waves in a dielectric material with $\varepsilon^* = 80$.

** Although human beings do not notice up to 5 - 15 V/m, some fish and animals respond.

*** Power for HP and PHS simply assumed to radiate for 4π direction at the separation of 10 cm. Note that the power is ten times higher at the distance of 3 cm which would be hazardous to health.

4.3 *Seismic unusual animal behavior as EM effects*

Metabolic increase of serotonin by the exposure of charged aerosols was alleged by Tributsch over the cause of unusual animal behavior and termed as "Serotonin syndrome".[2] However, the decrease in hypothalamic serotonin was detected in the experiment by exposure to EM waves.

Small animals like insects show unusual behavior first and then larger animals like rats, birds, cats, dogs, pigs and horses as an earthquake becomes nearer. The maximum occurrence was one hour before. The animal size effect might be explained as due to resonant absorption of seismic EM waves generated due to fractures of small asperities l of piezoelectric quartz grains leading to a pulse with a small pulse width of the l/β, where β is the velocity of seismic S-waves: High frequency components are more intense in a sharp pulse. The frequency then shift to the lower ones as the size of asperities increases. High frequency phenomena of seismic electric signals (SES) at 200 MHz which disturb color image of TV broadcast and 20 MHz disturbing radio wave observation of Jupiter were reported before the Kobe earthquake.[1,6]

Precursor statements that fish aligned or panicked indicate the electric field of more than 10 V/m in water and therefore about 80 times ($\varepsilon^* = 80$) in air, i. e., 800 V/m, as high as 1600 W/m^2 peak power ($S = (F/20)^2$) over the duration time of presumably microsecond. If the power is so high at the epicenter, human being may also be affected by the electric field of EM waves just as before thunder or climate change. Electrophysiological response to EM stimuli[1] would be a cause of unusual animal behavior before the earthquake. Charged aerosols might cause similar response, but will not cause a sudden surprise to fish as to force fish jump out of a pond onto a land.[6]

4.4 *EM waves as a method of communication*

Unknown communication method between separated animals was discussed by Sheldrake.[16] Although an idea of "*morphic resonance*" which transfer ideas or culture to animals with some unknown method was proposed, no particular physical quantity which transfer the information was suggested. I propose here that land animals are also sensing electric field of EM waves with a paw, tongue, hair as electrosensors just as some aquatic animals do. The field intensity is reciprocally proportional to the distance and so a long distance communication is possible at their resonant frequency. An animal sensitive to 10^{-6} V/m could detect 2.5×10^{-15} W/m^2. The size, shape and the inhomogenuity of animals in morphic resonance would play a vital role in the efficiency of information exchange if resonant absorption were involved. Future brain research will clarify that morphic resonance, if there were, is due to the resonant absorption of EM waves.

5. Conclusion

An absorption cross section of EM waves by a dielectric sphere was calculated to estimate the resonant absorption of EM energy. The prominent resonance was observed for $2\pi a = m\lambda$ for the wavelength λ and an integer m. The resonant absorption of seismic EM waves would be the cause for the shift of unusual behavior from small to large animals. The impedance matching of EM waves to the animals must be considered for physiological studies of EM waves. Enhanced noradorenaline and reduced selotonin were observed by the exposure to EM waves. Although presence of electrosensory organs would be the main reason for the sensitivity to earthquake precursors for some aquatic animals, land animals might detect EM waves through their conductive eyes or tongue judging from animal behavior. Systematic studies on hazards of EM waves has to be emphasized considering the resonant absorption at the handy phone frequency. Morphic resonance discussed by Sheldrake would be associated with animal detection of EM waves.

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