Effect of low pulsed microwaves on heart rate variability signals in mammals

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ABSTRACT

Objective: The main objective of this work is to study the effect of low pulsed microwaves on the heart rate variability signals derived from electrocardiogram signals of ten cats irradiated with pulsed microwaves with 5.655GHz.

Methods: Electrocardiograms of ten anaesthetized cats were measured and recorded using implanted electrodes before microwave exposure. Rectangular pulses at 5.655GHz, 2 w peak, 5.5us wide and repetition rate 2 Hz were applied to the brain of cats through horns and wave guides for 20 minutes, followed by a 20 minute recovery period after exposure.

Results: The results clearly indicate that the pulsed microwaves radiation induced high fluctuations in power spectra of heart rate variability signals specially in the band of 8s to 80s.(0.0125 Hz to 0.125Hz) which is related to the thermoregulatory control activity. Examining the power spectra of heart rate variability of recovery period (after 20 minutes microwave exposure) shows that the change of power spectra of heart rate variability signal during microwave exposure is not permanent.

Conclusion: The analysis of power spectra of heart rate variability signals of ten anaesthetized cats before, during and after exposure to low power microwave radiation seems useful to indicate the interaction of pulsed microwaves with cardiovascular system, autonomic function and body control mechanism.

Keywords: Heart rate variability, power spectra, pulsed microwave.

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One of the most interesting and widely recognized biological effects on microwaves is microwaves induced thermoelastic expansion.[1] A theoretical model based on thermoelastic expansion has been developed for brain spheres that are exposed to pulsed microwave.[2] This theory describes acoustic waves (with parameters of frequency, pressure and displacement) generated in the head as function of absorbed microwave energies in the brain. Actually, several studies reported successful use of pulsed microwaves to induce acoustic pressure waves in the brain.[2-4] Another studies of teratological effects concentrated on pulsed magnetic fields on chick embroys.[5-7] Typical example of these studies is reported by Koch and Koch.[7] They investigated the influence of pulsed magnetic field on chick teratology. In addition to 500us pulse repeated at 100 Hz which was used by Berman et al[6], Koch and Koch[7] used a 50us pulse with repetition rate at 33, 50, 1000 and 10 000 Hz respectively. The results of these studies showed the effect of pulsed magnetic field on check embryos. However, exposures to electromagnetic fields and microwaves have been reported to affect the cardiovascular system.[8-9] Investigation of cardiovascular changes during or after exposure to microwave irradiation produced by

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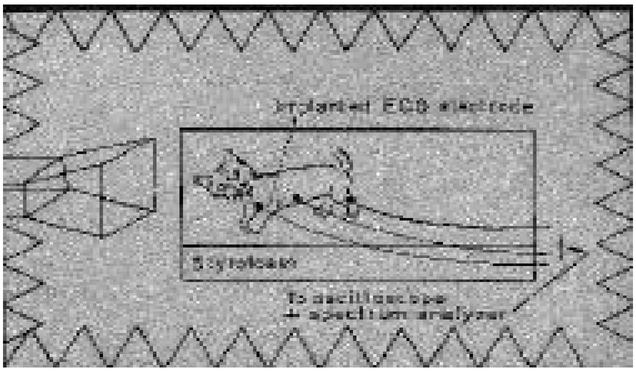

Figure 1 - Irradiation chamber configuration of 5.655 GHz microwave irradiation.

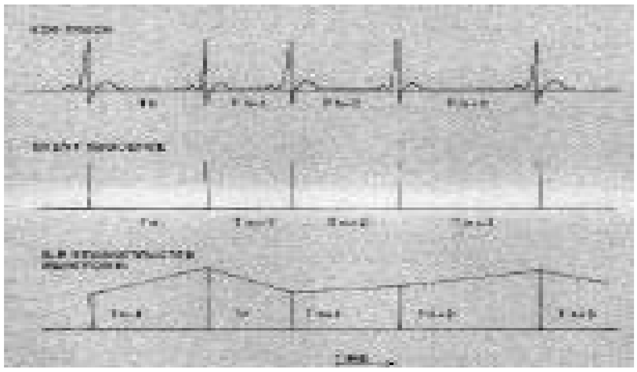

Figure 2 - Generation of heart rate variability signal derived from electrocardiogram (ECG).

other sources have not been reported. This study investigates the effect of low power microwave pulses on heart rate variability (HRV) signals in mammals, specifically, in cats. Normally,the heart rate variability signal is affected by respiratory, blood pressure and thermal stimuli.[10,11] These stimuli are mediated via autonomic nervous system (sympathetic and parasympathetic) to sinuatrial node (SAN) of the heart causing the heart variation.[12,13] The effect of pulsed microwave power specially, on HRV signal is not investigated specially its effect on cardiovascular body control mechanisms. This work presents the effect of microwave energy directed to the brains of ten cats irradiated with rectangular pulsed waves at 2 W Peak, 0.5 us wide and repetition period of 2 Hz at 5.655GHz on the body control mechanism manifested by auto power spectrum of HRV body signals before, during and after microwave exposure.

Methods. These experiments used ten male mongrel cats weighted approximately 4.5kg. In accordance with animal welfare, we comply fully with regulations and requirements including approval of ethical committee before experimental procedure, source(supplies) of cats, food, water, housing conditions-----etc. A microwave irradiation system was used to stimulate body control mechanism system in the animals head at 5.655 GHz, a radar transmitter, AN/sps-5D produced 0.5us wide pulses at a peak power of 2 W. Microwave energy was applied to the heads of cats via a narda model 643 standard gain horn inside 1.0 x 1.0 x 1.0 m microwave anechoic chamber. The heads of animals were located on the center line of the horn with average distance of 7 $\pm$ 0.5 cm which means that the max distance would be 7.5 cm and min distance is 6.5 cm. Since the distance from the microwave source and the head could vary by only factor of 1.07,this will not affect the microwave intensity exposed to animals head. In fact, we found no statistical significance on power spectra within this range. In all experiments, the animals (cats) were placed in the prone position facing the horn. When a large artifacts due to microwaves was seen in the output of ECG, attempts were made to reduce the artifacts by positioning the animals perpendicular to the direction of irradiation. Figure 1 shows some details of the experimental configuration. Actually, this apparatus is a modified form of Olsen and Lin.[1] The ECGs were recordeed onto FM recoreder at speed 4.75 cm/sec and played back at the same speed for analysis of HRV signal for 20 minutes before exposure,20 minutes during microwave exposure and 20 minutes during recovery period after exposure. The last 15 minutes of each session were utilized for analysis of HRV signals. The ECGs were band pass filtered between 0.01Hz to 100Hz and interfaced to PC with software package prepared by the author to detect R wave of ECG and then measure the time between successive R waves (Tn, T n+1,Tn+2 etc) which called RR intervals. This RR interval time is converted to a voltage which is directly proportional to that time. This voltage is connected to the next R wave ie the output voltage is proportional to nn th interval during n+1 th RR interval. The reconstructed voltage signal as shown in Figure 2 may now placed as HRV signals and can be directed to Pentium PC to obtain the auto-power spectra of HRV signals using auto-Regressive Moving Average package prepared by the author.

The experimental procedure here in this paper is based on measurement of ECGs and derived HRV signals of cats (Figure 2) exposed to microwave irradiation as explained in apparatus section and showed in Figure 1. The experiments used cats where ECG electrodes were surgically implanted approximately 0.5 cm deep in thoracic of anaesthetized cats through two holes drilled in the chest and one hole in the left leg. Next during continued (Ketamine HCI, 150mg/kg.i.m), the Animal and ECG implanted electrodes assembly, resting on a block of foamed polystyrene were taken

Table 1 - Mean heart rate and ± SEM before, during and after experiments.

	Mean Heart Rate (beats /min)	± SEM
Before experiments	180	± 7
During experiments	195	± 17
After experiments	185	± 6

to the area of microwave anechoic chamber, with ambient temperature maintained at 22 C, where microwave pulses of 5.655 GHz exposed to the brain of the animal (Cat). Heart rate variability signals (extracted from R-R interval of ECG measured as shown in Figure 2) were measured and recorded before and during microwave exposure. Following the exposure to 5.655 GHz microwave pulses, 20 minutes of recovery period is allowed, followed by 20 minutes of HRV signal recording after this recovery period. Simultaneously, all signals measured (ECG, HRV) for microwave pulses at 5.655GHz were fed to the spectrum analyzer or Pentium PC such that both time series of HRV signals and auto-power spectrum domain could be obtained before, during and after the exposure of microwave pulses at 5.655GHz. The difference in the low frequency spectrum energy before, during and after exposure to microwave irradiation between the ten cats was analyzed and considered statistically significant using one way analysis of variance with repeated measures ($P>0.05$).

Results. The mean heart rate for cats before experiments was 180 beats/min, during experiments was 195 beats/min and after was 185 beats/min. Table I shows the mean heart rate and its standard error of mean before, during and after experiments. Table I Mean Heart rate and + SEM before, during and after experiments frequency is 2.5 Hz and the bandwidth of HRV signal does not exceed 0.5 HZ) and then filtered by low pass filter to prevent aliasing, then auto-regressive moving average method (ARMA) was applied to these signals to produce the power spectra. Figure 3 and Figure 4 show the average power spectra of HRV signals for ten cats before and during exposure to 5.655 GHz in chamber respectively. Figure 5 illustrates the average power spectrum of HRV signals after 20 minutes recovery from microwave exposure.

Discussion. This study is the first study to the author's best knowledge to report on low frequency oscillations exist in the power spectra of HRV of animals exposed to pulsed microwaves irradiation. Other studies[1-4] examined the experimental

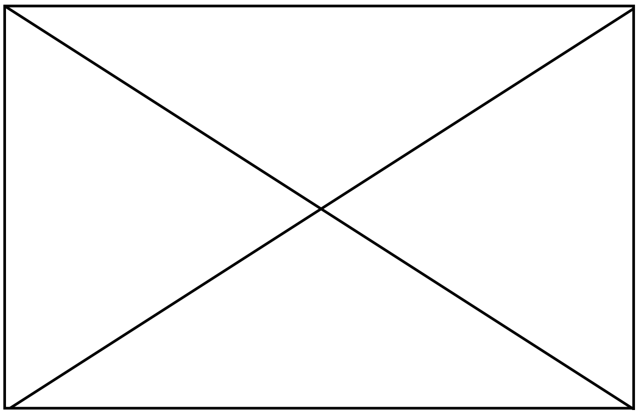

Figure 3 - Average auto-power spectrum of HRV signals for ten cats before exposure to 5.655 GHz in chamber at 2W.

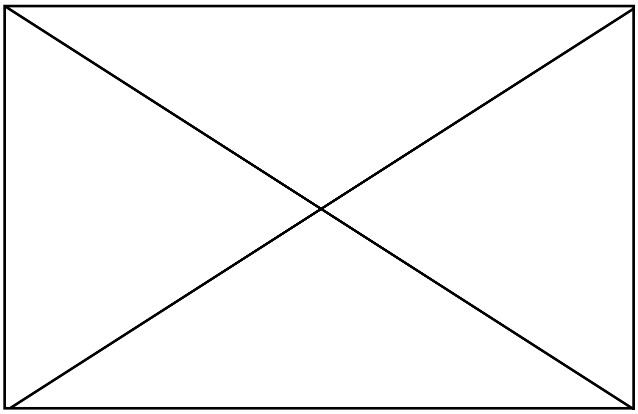

Figure 4 - Average auto-spectrum of HRV signals for ten cats during exposure to 5.655 GHz in chamber at 2W.

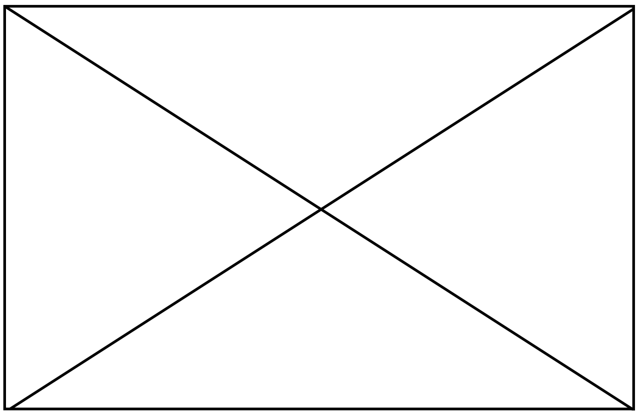

Figure 5 - Average auto-power spectrum of HRV signals for ten cats after 20 minutes of recovery period of microwave exposure to 5.655 GHz in chamber at 2W.

observation on electrical events that occur along the auditory pathways in response to pulsed modulated microwave stimulation. Also, intensive investigation of possible biological effect of magnetic field are reported by.[5-10] Comparing Figure 3 with Figure 4, it is clear the rising power amplitude of the auto-power spectrum of HRV signal during exposure to the pulsed microwave irradiation at 5.655 GHz specially the appearance of distinct peak at nearly 0.033Hz which lies in the frequency band of 0.033Hz ñ0.125Hz as shown in Figure 4. This frequency (0.033Hz) distinct peak is usually referred to thermo-regulatory control oscillations.[8-11] One possible physiological interpretation of increasing power amplitude of auto-power spectrum of HRV signals in the band 0.0125-0.125 Hz after exposure to microwave energy at 5.655 GHz is as fellow: When microwave irradiation impenges on the head of cats,a portion of the absorbed energy is converted into heat which produces a small but rapid rise in temperature in cranial tissues.[3-4] This rise in temperature in very short time may affect the body control centres in the brain and produces thermo-regulatory oscillations where the autonomic nervous system mediated these oscillations to sinu-atrial node (SAN) of the heart and appeared as peak at nearly 0.033Hz in the power spectrum of HRV signal during exposure to microwave irradiation as shown in Figure 4. Actually, this pulsed microwave irradiation may stimulate the body control centers of the brain including the brain stem and hypothalamus in the brain[12] and entrain the auto-power spectrum of HRV signal with thermo-regulatory control oscillations.[14-19] It seems that as shown in Figure 4 that the power spectrum of HRV signal of cats exposed to pulsed microwave energy is mostly influences by 0.033Hz distinict peak which is related to vasomotor thermal activity indicating the heating effect of pulsed energy on the brain. This would increase the temperature of the brain and leads to pathological effect.[1,2,12,14] The appearance of this frequency oscillations (0.033Hz) of thermo-regulatory control system in auto-power spectra indicates the effect of microwave irradiation on thermo-regulatory control system of cats. Actually, Sayers[11] demonstrated the independence of thermo-regulatory oscillation from the blood pressure control oscillation (Herring-Traube oscillations). Kitney[12] showed the influence of thermo-regulatory oscillations in power spectra of HRV signal or perephrial blood flow with the same influence of thermo-regulatory oscillations in blood pressure signals. Looking to Figure 5, which shows the auto-power spectrum after 20 minutes recovery period, it is obvious the disappearance of distinct peaks at 0.033Hz which indicates that 20 minutes recovery period of microwave exposure, the change of HRV auo-power spectrum of HRV signal is not permanent. This finding may be significant for knowing the physiological effect of the use of cellular or mobile telephone on the body and specially on the brain.

In summary, acute exposure of cats to microwave exposure had significant on HRV signal. The techniques that have been developed in our laboratory to measure HRV signals may be used to include other body signals such as blood pressure and peripherial blood flow signals to evaluate potential effect of microwave exposure with different microwave power and frequencies.

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