VARIATIONS OF THE SOMATOSENSORY EVOKED POTENTIALS DUE TO MICROWAVE FIELDS IN RABBITS SPINAL CORD

Jian TENG, Damien CARTON de TOURNAI, Fabienne DUHAMEL and André VANDER VORST

Université Catholique de Louvain
Microwaves Laboratory
B-1348 Louvain-la Neuve, Belgium

ABSTRACT

The paper presents an in-vivo experiment concerning cerebral evoked potentials of rabbits, without and with microwave irradiation of the spinal cord at 4.2 GHz. There is ample evidence of microwave effects. A first careful calculation of the absorbed power seems to show no evidence of a non-thermal effect on the nervous system.

INTRODUCTION

This research is in area of the action of electromagnetic fields on the transmission of the nerve impulse. The experiment presented in this paper is an "in-vivo" experiment concerning the electro-corticogram measurement. The nervous system reaction to microwave fields is investigated by observing the variations of the somatosensory evoked potentials (SEP) due to microwave irradiation on the spinal cord in rabbits. In the experiment the nerve impulses are generated on the superficial peroneal nerve (SPN) by an isolated electric stimulation. With an AgCl electrode, we measure the SEP on the cortex (area SI). The segments of the spinal cord are the compulsory channel through which the induced nerve impulses generated in SPN are transmitted to the brain. The microwave applicator is inserted at the level of the lumbar vertebrae and placed in the epidural space posterior to the spinal cord. This way, the microwave field can entirely or partially cover the mentioned segments, according to the interest of the research.

In our research on thermal and possible athermal effects of microwaves on the nervous system, this experiment comes after two previous ones: the behaviorial experiment and the pharmacological experiment. The results of these experiments showed that by applying microwaves to the peripheral nervous system (in some acupuncture points), analgesic effects are obtained on rabbits: microwave irradiation can increase the pain threshold and decrease the concentration of norepinephrine in the hypothalamic preoptic area at the same time [1]. This phenomenon is similar to that obtained by electric acupuncture and the warm-needling.

Have microwaves other effects than thermal ones? The present experiment is prepared with this question in mind. Thermal effects due to microwaves increase with the duration of irradiation. In this electrophysiological experiment, we limit the duration and analyse the data expecting to be able to separate thermal and possible athermal effects.

METHOD

The microwave energy is radiated by an asymmetrical dipole at the head of the applicator. This coaxial-line applicator covered by a dielectric layer, about 1 mm in diameter, has a radiating gap in the outer conductor [2].

In order to evaluate the power deposition quantitatively, we have modelled an asymmetrical dipolar antenna in the spinal cord of a rabbit. The electromagnetic field of an insulated antenna in a dissipative medium has been evaluated using King's formalism [3]. Zhang et al. have developped this method in the case of an insulated asymmetrical dipole antenna [4]. In both cases however the dissipative media is assumed to be homogeneous. In order to take into account the reflections caused by the nearby spine (namely bone), we have improved the precedent modellings by introducing in our calculations a ray method [5]. Then the interface is identified with a number of image applicators (one, two or three images according to the observed point) located in the side of the surrounding medium. By doing so, the problem of the single applicator near the interface is replaced by that of an applicator array consisting of a number of applicators in a homogeneous dissipative media.

In the experimental setup, the microwave applicator has been placed in the spine and located in the extradural cavity reclining on the spinal cord by a pereutoneous technic for two days before the experiment. The reflection coefficient is then measured by means of a vector network analyzer to determine the transmitted power.

The rabbit known in Belgium as "New Zealand Albinos" (about 3.5 kg) is anaesthetized (urethane 0.6 g/kg, by intravenous injection) and put on a stereotaxic instrument. The cranium is trephined to have access to the brain and an AgCl electrode is put against the cortex (SI region). This allows to measure the evoked potentials induced by the electric stimulation on the SPN. Start and duration of the electric stimulation and of the microwave irradiation are automatically controlled. The measured potential is continuously amplified, digitized and stored in the ROM of the PC by an interface card (I/O). The microwave irradiation is directly applied on the spinal cord (near L1 and L2 segments) in three ways (Figure 1). (1) Pulse irradiation: the width of the microwave pulse is about 200 ms with a repetition period of 6 seconds, the trigger of the microwave generator being synchronised with the isolated stimulator. (2) Discontinuous irradiation: identical with the previous way except that the width of the microwave pulse has been extended to 3 seconds. (3) Continuous irradiation: we continuously apply microwaves.

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Five rabbits have been sacrificed in this experiment. The microwave frequency is 4.2 GHz and the electric pulse exciting the SPN is about 15 V during 1 ms.

RESULTS

The diameter of the spinal cord is on average 7 mm. We have plotted the longitudinal power deposition in the axis of the antenna (Figure 2a). We have then plotted the transversal power deposition at different points :

- at the plane of the gap , i. e. at 0.0 mm (Figure 2b)
- at 8 mm from the gap (real pole) (Figure 2c)
- at -6 mm and -24 mm from the gap (effective pole) (Figures 2d,e).

All the curves have been plotted for an absorbed power of 0.8 W. It is to be noted that the iso-power lines are very concentrated around two maxima areas, one near the real pole and one near the effective pole. This is probably due to the reflections at the interface between the spinal cord and the adjacent bone, and also to the very small distance between the observed points and the applicator.

Figure 3 shows the frequency behavior of the reflection coefficient from 0 to 10 GHz. As it can be seen, the reflection coefficient is equal to about -7 dB at 4.2 GHz (the working frequency). By taking into account the attenuation along the antenna and neglecting the reflection coefficient at the gap level (since the antenna is adapted at 4.2 GHz, Figure 4), we find a transmitted power of 0.4 W for an incident power of 1 W (Figure 5). In the same way, for an incident power of 2 W, the transmitted power is found to be equal to 0.8 W.

There is no effect with short pulse irradiation (0.2 s every 6 seconds) under an incident microwave power of 2 W on peak latencies and in wave shapes of SEP (Figure 6). In some cases with continuous irradiation and the same microwave power the rabbits became reactive to the irradiation (acceleration of breathing and orientation reflex,...). So the emitted microwave power was decreased to 1 W. No reflexive activity was observed when irradiating the spinal cord up to 15 min. However, peak latencies and wave forms change in these conditions (Figure 7).

For two rabbits, we present the wave amplitudes and the peak latencies as a function of the duration of microwave irradiation (Figures 8a and 8b, respectively). The experimental conditions are as follows.

1. A continuous microwave irradiation is applied in the spinal cord and the incident power is 2 W.
2. The electrical pulse is applied every 2 seconds during 30 or 6 seconds during 60 seconds.

From the stored samples, we have extracted the amplitude and latence for each response. In the same figures, we have also plotted the least squares linear approximation of the measurements. As it can be seen, the microwave signal makes the amplitude and latence of SEP decrease.

CONCLUSION

From the experimental and theoretical work, we infer the following conclusions.

1. Power deposition calculations clearly attest that we obtain very high values of power deposition at localized points which can lead to a temperature increase.
2. If microwave irradiation is applied for a long period of time, we observe reversible variations of the SEP. These variations however may be due to an increase of the temperature in the spinal cord. Figure 7, indeed, clearly shows that after having stopped the microwave irradiation, the amplitude and latence of the SEP tend to recover their original responses. Moreover the application of a short pulse irradiation (0.2 s) every 6 seconds does not modify the SEP, as it may be unable to increase temperature.

Calculation of possible thermal effects (with respect to the normalized power deposition) and statistical treatments of data are still in progress.

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REFERENCES

[1] J. TENG, Hongqu YAN, D. VANHOENACKER, A. VANDER VORST, "Variations of pain threshold and norepinephrine release in rabbits due to microwave stimulation", IEEE MTT-S Int. Microwave Symp. Dig., pp. 801-804, Boston, June 1991.

[2] J. TENG, A. VANDER VORST, "Microwave field in rabbit spinal cord and its influence over the Pf nociceptive discharges evoked by noxious stimulation on SPN", Proc. IEEE Microwaves in Medicine, pp. 173-176, Rome, October 1993.

[3] R. W. P. KING, B. S. TREMBLY, J. W. STROBEHN, "The electromagnetic field of an insulated antenna in a conducting or dielectric medium", IEEE Trans. Microwave Th. and Tech., vol. 31, n° 7, pp. 574-583, July 1983.

[4] Y. ZHANG, N. V. DUBAL, R. TAKEMOTO-HAMBLETON, W. T. JONES, "The determination of the electromagnetic field and SAR pattern of an interstitial applicator in a dielectric dissipative medium", IEEE Trans Microwave Th. and Tech., vol. 36, n° 10, pp. 1438-1444, October 1988.

[5] J. TENG, H. YAN, D. VANHOENACKER, A. VANDER VORST, "The near field and SAR pattern of an insulated asymmetrical dipole applicator in a dissipative dielectric medium", Proc. 22th EuMC, pp. 287-292, Helsinki, September 1992.

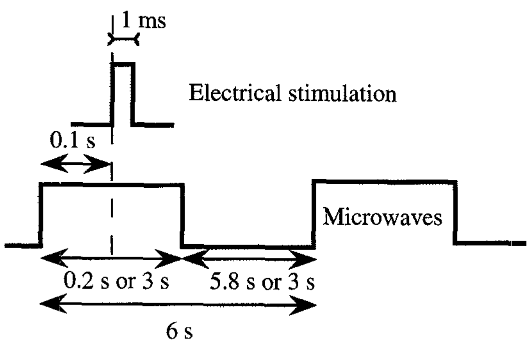

Figure 1 Experiment sequence :
-an electrical pulse stimulation (width 1 ms, 0.1 s after the microwave irradiation start),
- microwave irradiation period:
  - 0.2 s every 6 s
  - 3 s every 6 s
  - continuous
- continuous record of the cortex potential.

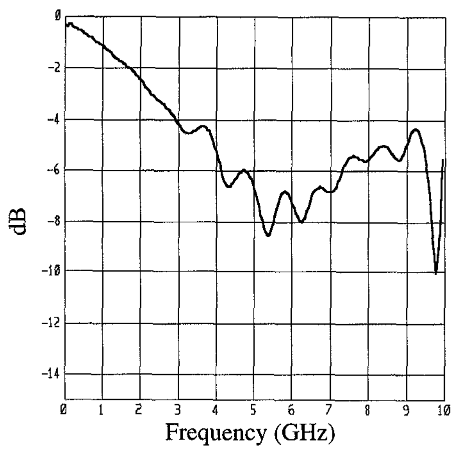

Figure 3 Measured reflection coefficient of the dipole antenna inserted in the spinal cord of an anaesthetized rabbit.

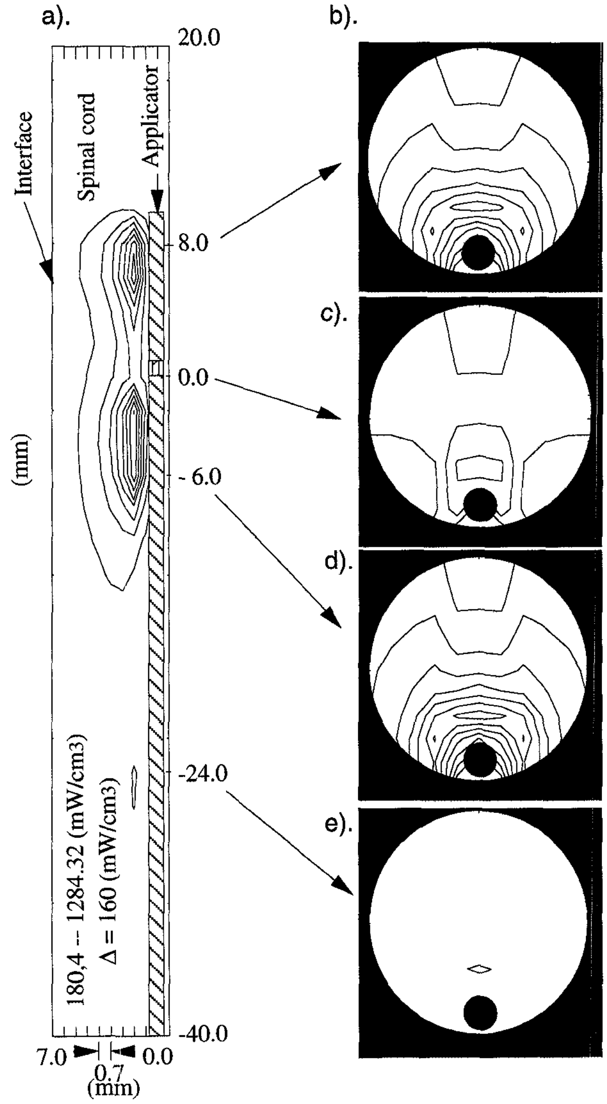

Figure 2 Power deposition for an absorbed power of 0.8 W.
a) Longitudinal power deposition (in the axis of the antenna).
b), c), d), e) Transversal power deposition at different levels.

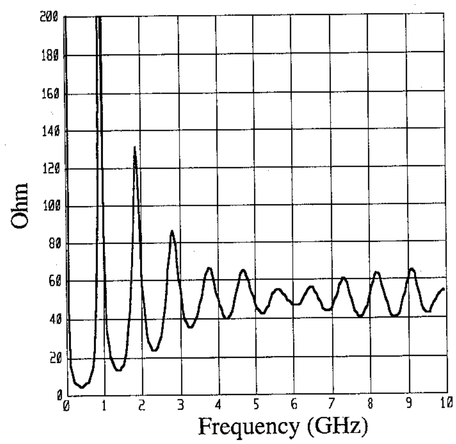

Figure 4 Calculated radiation resistance of the antenna.

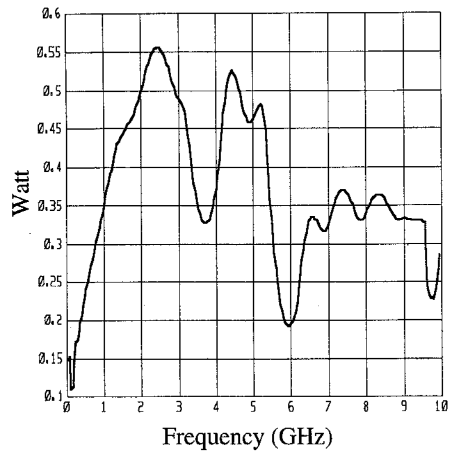

Figure 5 Transmitted power by the antenna for an incident power of 1 W.

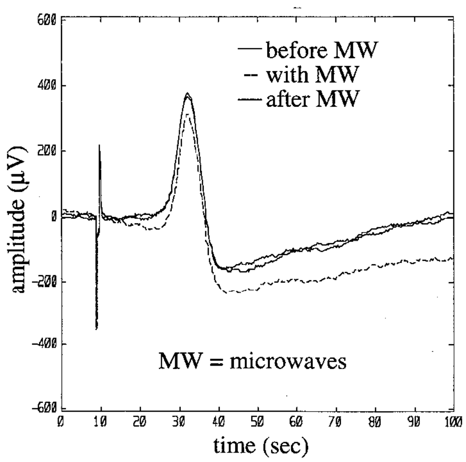

Figure 6 SEP with or without short pulses irradiation (0.2 s every 6 s under an incident power of 2 W). Each plot is an average from 30 measurements.

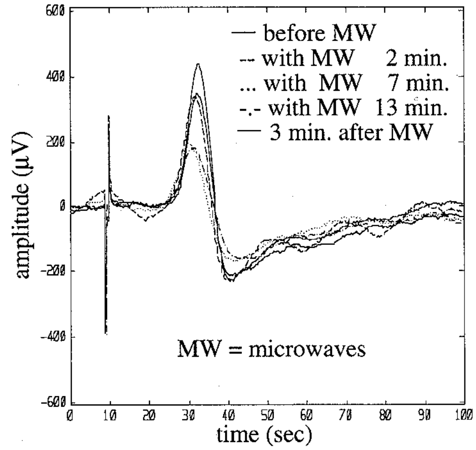

Figure 7 Evolution of the SEP at different times under continuous microwaves (incident power of 1 W and irradiation during 15 min.). Each plot is an average from 30 measurements.

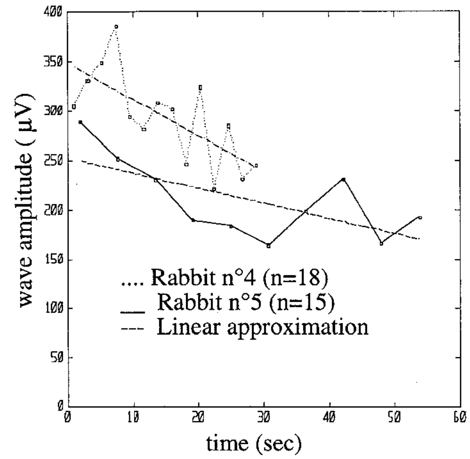

Figure 8a Evolution of the wave amplitude as a function of irradiation duration with 2 W continuous microwaves; n is equal to the number of SEP measurements.

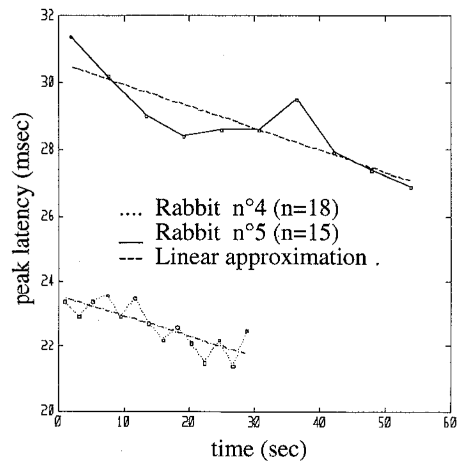

Figure 8b Evolution of the peak latency as a function of irradiation duration with 2 W continuous microwaves; n is equal to the number of SEP measurements.