ANALYSIS OF MICROWAVE EFFECTS ON ISOLATED HEARTS

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ABSTRACT

Heartbeat stimulation and regularization effects of microwaves on the electrical activity of isolated chick embryo hearts are analyzed. The hearts were exposed to low-power pulsed modulated electromagnetic waves at 2.45 GHz. The results can be explained by studying the correlation between the cardiac and the modulation waveforms.

INTRODUCTION

Evidence of low level microwave effects on both living or isolated hearts has been reported by several authors [1],[2],[3],[4],[5].

Our previous experiments showed that low intensity pulse modulated microwaves at 2.45 GHz can affect the heartbeat of isolated chick embryo hearts [6],[7],[8]: by increasing the modulation frequency above the natural imperturbed heart rate, the heartbeat changes with it. In presence of arrhythmia, a proper pulse repetition frequency regulates the beat. However, the measurement system we used did not allow us to show how such effects were correlated to the modulation waveform.

By means of the McAllister, Noble and Tsien model for the electric activity of the Purkinje fibers [9] and further modifications [10],[11], we showed how a current pulse acts on the electric response of the beating cells, depending on the instant of application [12],[13].

EXPERIMENTAL SETUP

In order to verify if the above theoretical results were also suitable with superimposed microwave fields, we improved the measurement setup: a data logger was used and more reliable values were achieved [14],[15], elaborated with an analysis program made "ad hoc".

The new measurement system is shown in Fig.1.

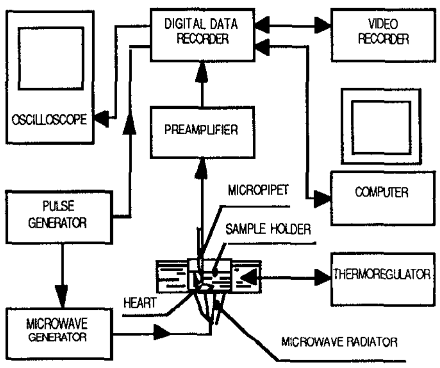

Fig. 1 - Measurement setup.

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Experiments were performed on 8-9 days old isolated living hearts of chick embryos. Each hearth was kept in oxygenated Ringer's solution at 37 °C in a Petri dish. The biological sample was irradiated through the bottom of the holder by means of a tapered, open coaxial section. A high resistance (about 1 MΩ) glass micropipet, filled with Ringer's solution, was inserted near the sinus-atrial node, by means of a micromanipulator, in order to pick up the cardiac signal. To minimize the radiofrequency coupling to the micropipet, the internal electrode was made of carbonated teflon (R > 100 kΩ).

Both the cardiac and the modulation signals were recorded on videotape, the cue level indicating the irradiation periods. These signals were also displayed at once on a memory oscilloscope for immediate examination and were successively analyzed. The behaviour of the instantaneous frequencies versus time were also determined.

During the experiments, the hearts were irradiated with 2.45 GHz pulsed microwaves, with a peak power of 10 mW and 10% duty-cycle. The estimated incident peak power density was 3 mW/cm^2 [7]. The repetition frequency was

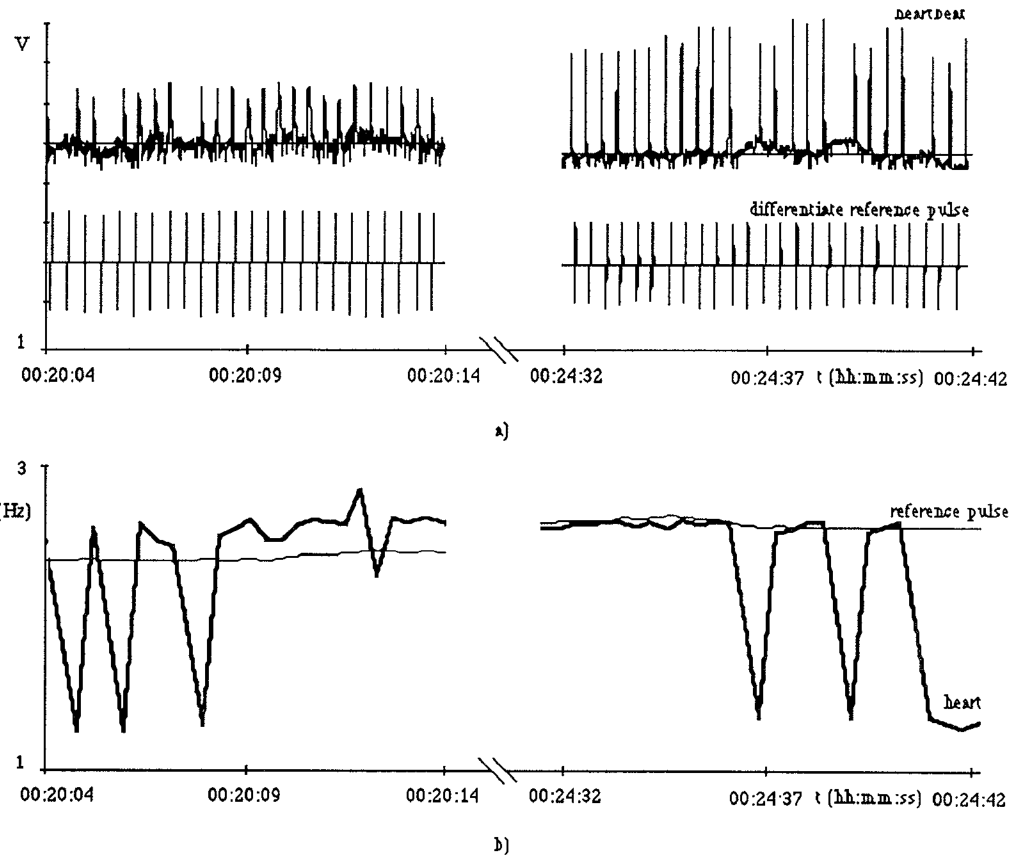

Fig. 2. Regulation and variation of the heartbeat by microwaves. *(a)* As the pulse modulation frequency increase the beat becomes stable at about the same rhythm; irregularities occur again as the pulse repetition rate goes up more. *(b)* Instantaneous frequencies of heart and modulating pulses.

within normal physiological limits (1÷3 Hz).

At present, the data recorded during a 2÷6 hours period for each heart have been partially examined.

RESULTS

The previously observed effects, such as stimulation and heart regularization when arrhythmia occurs, have been confirmed.

Special care was dedicated to the analysis of the time position of the modulating pulse with respect to the heartbeat when above effects occur. To explain some results, two examples of this analysis are reported here (the micropipet insertion instant is assumed as zero time).

Fig. 2,a shows an heartbeat regularization phenomenon. Before being irradiated, the heart rhythm was rather irregular. When microwaves with a pulse repetition rate of 2.4 Hz were tuned on, the heartbeat became regular at about the same frequency. By increasing the modulation frequency, the heartbeat increased likewise, until, above 2.65 Hz, the heart came back to beat irregularly (Fig. 2,b).

In the experiment shown in Fig. 3,a, the heart was beating at a regular frequency, stimulated by irradiation. A few seconds after microwaves were switched off, an arrhythmia occurred (Fig. 3,b). By applying microwaves again, a regular beat appeared in about 7 seconds (Fig. 3,c).

A detailed analysis performed in the time domain revealed that regularization occurs when the modulation pulses, at frequency close to the natural imperturbed heartbeat, were applied in the diastolic phase, as it is shown in Fig. 3,d.

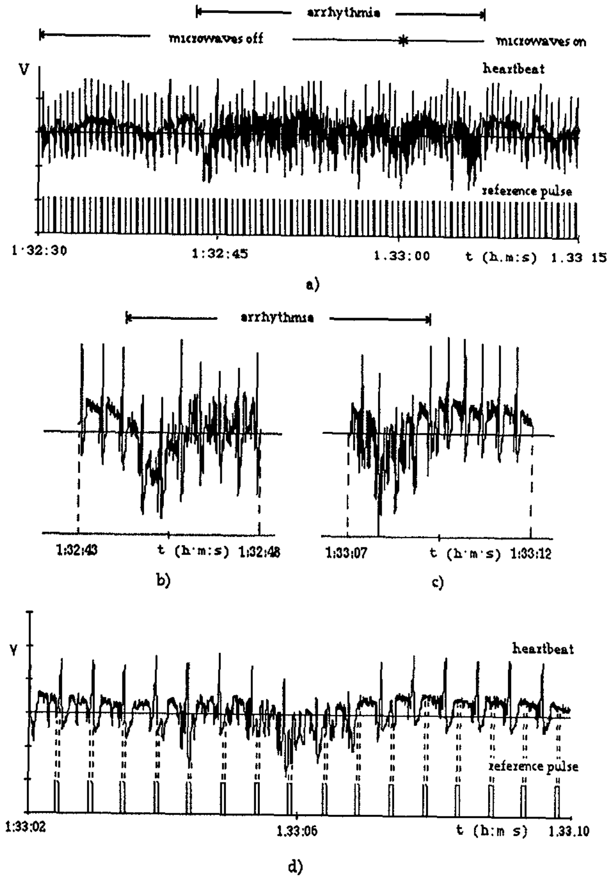

Fig. 3. An example of heartbeat regularization by pulsed microwaves *(a)*. A few seconds after microwaves are switched off an arrhythmia occurs *(b)*; when the microwaves are switched on a regular beat appears *(c)*. Evidence of the regulation effect during the diastolic phase *(d)*.

CONCLUSIONS

These results will allow us implement the model for identifying the interactive mechanism. This is useful for the optimization of the interaction, in view of possible clinical applications in the field of heart stimulation.

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