Artifacts caused by microwave radiation in cardiac radio telemetry

A B Simakov, B V Gurkovskiy, E M Onishchenko, N Y Trifonova and D S Veselov
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, 115409 Moscow, Russian Federation

Corresponding author e-mail address: absimakov@mephi.ru

Abstract. The effect of the cardiac radio biotelemetry on human heart rate variability has been investigated. The burst transmission mode with a high duty cycle minimizes the influence of microwave artifacts on the reliability of transmitted data.

1. Introduction
Radio telemetry is one of the main techniques of humans’ physiological parameters registration at their free behaviour and a cardiac signal is the most important factor in the assessment of their psycho-physiological state. Usually, the cardiovascular reactions to microwave exposure by the heart rate variability (HRV) analysis are evaluated [1,2]. Well-developed algorithms and software for HRV analysis, corresponding to the today’s international standards [3,4] were developed. Recently assumed, that low power telemetry transmitters had no effect on the human cardiovascular system (CVS). However, in the last decade shown, that even low-intensity electromagnetic fields (EMF) might change cardiogram parameters [5]. Therefore, this work focuses on the study of artifacts arising when measuring the physiological parameters, in particular, HRV, due to exposure to microwave radiation from the cardiac telemetry data channel.

2. Research procedure and experimental installation
Figure 1 illustrates the details of suggested research procedure and experimental installation.

Figure 1. (a) Block-diagram of the instrumental set and (b) photo of the person under study.
The experiment involved 25 volunteers (15 men and 10 women) aged 19 to 63 years. They participated in the investigation in compliance with all ethical standards and safety regulations. During the experiment, the volunteer was located in a well-shielded room as shown in figure 1(b). At the beginning of the study, before EMF exposure, the volunteer was in a free state and his heart rate was recorded by pair of optical photoplethysmography (PPG) sensors marked by 2 in figure 1(a). Then he has been irradiated in a blind mode by externally controlled microwave source within the frequency and power range of mobile GSM Standard (frequency band of 930 – 960 MHz and energy flow less than 50 μW/cm²). Simultaneously, we were recording a cardio-intervals-gram (CIG).

The microwave generator indicated by 1 in figure 1(a), simulates the GSM based radio telemetry transmitter used in cardiac monitoring. Figure 2(a) shows its photo.

To measure the absorbed dose and to monitor microwave radiation level in safety control system we used a new portable bio-dosimeter [6] marked by 4 in figure 1(a). Figure 2(b) shows a photo of the bio-dosimeter.

A control board indicated by 5 in Figure 1(a) manages all devices of the research installation and performs the preliminary data processing. Control computer labeled by 6 in figure 1(a) records data and transmits it to a remote server labeled by 3 in figure 1(a) for final processing and storage the measured information.

Figure 2. The photos of (a) simulator of radio telemetry transmitter and (b) portable bio-dosimeter.

3. Details of the study
The features of radio telemetry system operation were simulated by three timing protocols. All protocols started with five-minute initial testing before microwave exposure and ended with the same back-end testing after microwave exposure.

The first protocol simulated a rapid data radio transmission. The duration of one microwave exposure session was 30 seconds with a one-minute break. It was followed by a five-fold repetition of this session. The second protocol involved the following sequence of operations: three minutes of radiation exposure and a three-minute break with a three-time repetition of the session. The third protocol was a model of the six-minute long session without repetition.

We used the following methods for HRV visualization, analysis and parameters evaluation: the distribution of heart rate intervals; histograms of CIG; power spectral density (PSD) of CIG; autocorrelation of CIG and scattered charts analysis. Figure 3 shows an example of experimental heart rate intervals distribution: before and after the microwave radiation when a volunteer in accordance with a second protocol was tested.

The results demonstrate very large differences in individual sensitivity of people to low-intensity microwave radiation. They show a high individual sensitivity of the specific persons to weak microwave signals simulating the signals of GSM based real radio telemetry systems used in cardiac monitoring. This suggests the possibility of significant side effects i.e. artifacts with commonly used methods of data measurement and transmission in the cardiac monitoring.
The statistical estimations of these effects for 25 persons and three timing protocols have been performed, which simulate the effects of remote monitoring systems in cardiology shows the following:

- under microwave irradiation in accordance with the first protocol no significant changes of the cardiac rhythm were detected;
- under exposure in accordance with the second protocol, 70% of the persons had an increase in a heart rate of 3 – 4 beats per second;
- under exposure in accordance with the third protocol, almost 86% of the subjects had the individual drift of HRV and for 28% of them, the drift did not disappear in five minutes after exposure.

![Figure 3](image.png)

**Figure 3.** The histograms of experimental heart rate intervals distribution according to the second-time protocol: a) before EMF action; b) after EMF exposure.

### 4. Conclusion

Experimental modeling of the side effect of radio telemetric systems on human cardiac signals demonstrated their peculiar sensitivity to low-intensity transmitter irradiation in the microwave range. The transmitting signals can change cardiac activity and produce, so-called biological artifacts, providing the data corruption. At the first time protocol (30 sec of EMF), no significant changes of the cardiac rhythm were detected. The increasing of exposure duration leads to artifacts. Therefore, the reduction of bio radio telemetry artifacts is possible by accumulation data and transmission them in a burst mode with a large duty cycle.

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