MICROWAVE MEASUREMENT OF RESPIRATION

by

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ABSTRACT

A non-contact microwave technique is described which measures respiratory movements of men and animals. The technique is based on the scattering of continuous wave radiation. Results are compared with a thermister flow transducer for both men and animals, indicating the usefulness of the procedure.

Introduction

The determination of respiratory system functions is important for both diagnostic and therapeutic medicine. Measurements of respiratory air flow, volume and efficiency of gas transfer from the alveoli (small air sacks) in the lungs to the blood provide valuable diagnostic information. Continuous monitoring of respiration activities in recovery rooms and for patients with impending or existing respiratory failure is also essential to assess the function of the vital respiratory organs. In addition, during the first days of life, premature and low-birth-weight infants often have apneic spells which may require continuous monitoring.

The rate of breathing is the simplest test of respiratory function, and it is most commonly done by inspecting the color of skin and mucous membranes. This, however, is both time consuming and demanding on the part of health care personnel, and it does not lend to situations where continuous monitoring is required. Although a number of techniques exist for continuously monitoring respiration, none of them is completely satisfactory[1,2]. Therefore there is a need for a reliable means to monitor respiration.

In this paper we present a technique using microwave radiation in measuring the respiratory movements of man and animals. A beam of microwave radiation is directed toward the upper torso of the subject, the reflection from the chest is compared to the transmitted energy, and the resultant signal is measured to give respiratory information. The method is simple, noninvasive and does not require any contact with the subject; in fact, the subject may be fully clothed.

Method

A block diagram of the continuous wave microwave respiration monitor is shown in Figure 1. Microwave energy is derived from an X-band sweep oscillator which has a maximum output of 10 milliwatts. In the experiments described in the following section, the output frequency of the source was adjusted to 10 GHz and the incident power density was estimated to be in the microwatt per square centimeter range. The forward signal was passed through a variable antenuator and a 20 db directional coupler before being radiated through a rectangular horn. Upon incidence on the subject the microwave signal is modulated both in amplitude and in phase by the moving chest wall. The scattered energy modulated by the respiratory movements was detected by a crystal detector mounted on a receiving horn. This signal was led to the ratio meter where the amplitude was compared with a portion of the forward signal detected by a similar crystal attached to the directional coupler. The ratio meter computed the instantaneous ratio between the scattered and the reference signals. The output of the ratio meter is a voltage whose frequency corresponds to the rate of respiration through the standard equation for amplitude modulated signal

$$v(t) \sim 1 + \cos \omega_r t$$

where $\omega_r = 2\pi f_r$ and f_r is the frequency of the moving chest wall.

The microwave measured respiratory activity was also compared with a commercial hot wire anemometer air flow transducer. The outputs from the microwave respiration monitor and the hot wire anemometer pulmonary function analyzer were capacitively coupled to a dual trace oscilloscope and recorded using a dual channel strip chart recorder.

Measurement

A 5.1 Kgm albino rabbit was the subject of one series of experiments in which it was confined to a cardboard box but not anesthetized. The air flow transducer was attached to the inlet of a plastic mask which was placed over the rabbit's head. The distance between the horn radiator and the rabbit was approximately 30 cm. The receiving horn was located either right next to the transmitting one or at an angle, but was always aimed at the chest of the rabbit. A typical strip chart recording is shown in Figure 2. Notice that the hot wire anemometer recording is related to the absolute value of respiratory flow. Therefore, it is twice the rate of respiration.

The results for a seated human subject breathing deliberately at approximately 51 times a minute is shown in Figure 3. The upper traces in these figures are microwave measurements and the middle curves are the air flow measurements. The bottom lines are time markers at one second intervals.

Conclusions

It can be seen from Figures 2 and 3 that the continuous microwave technique is very useful for respiratory measurements. The comparative microwave and anemometer measurements also indicate that it may be possible to use microwaves to assess respiratory volume as well. (The output voltage of the hot wire anemometer flow meter corresponds approximately to 0.1 volt/liter/min.) In fact, Moskalenko[3] has suggested the use of changes of microwave reflectance and transmittance as a measure of physiologically significant parameters such as circulatory and respiratory volume changes.

This method has several advantages over more conventional techniques because it does not require any direct contact with the subject. Problems such as skin irritation, restriction of breathing and loose electrode connections are easily eliminated. Moreover, the use of ratio measurement makes the stability of the oscillator frequency an unimportant question. In this paper, results using a number of other species will also be discussed.

References

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3. Iu. Ye. Moskalenko, "Application of EM Radio Waves for Non-Contact Recording of Changes in Volume of Biological Specimens", Biofizika (English transl.), Vol. 5, pp. 225-228, 1960.

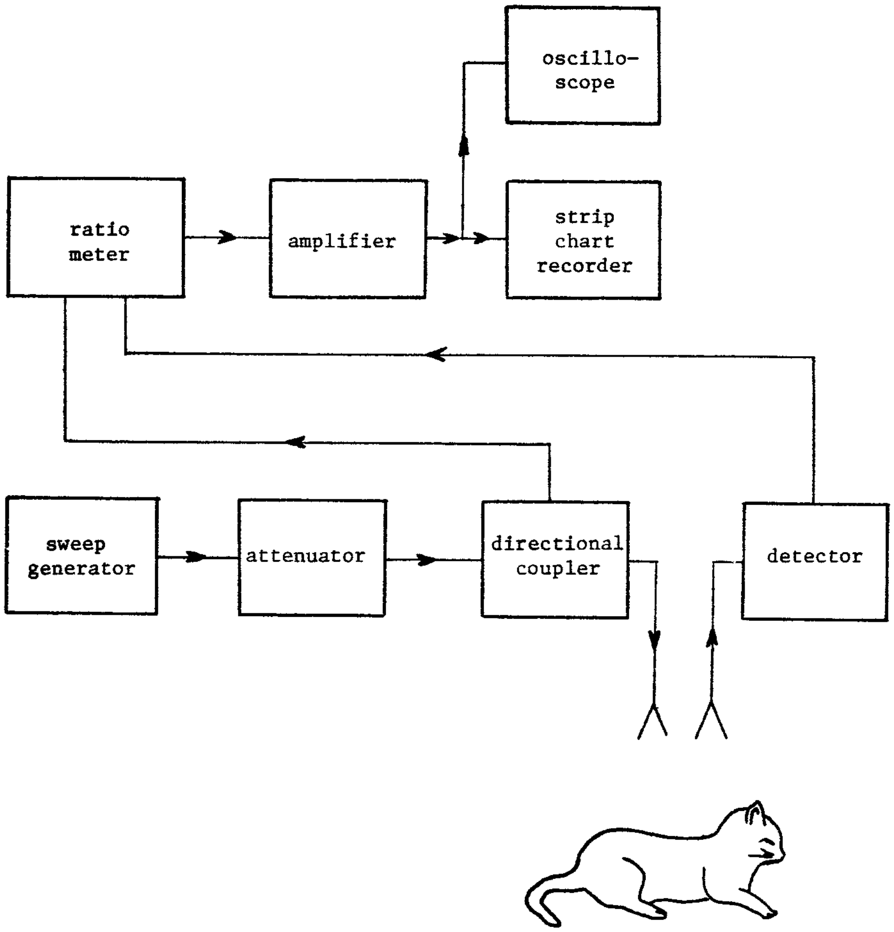

Figure 1. Experimental setup of non-contact microwave respiratory measurement.

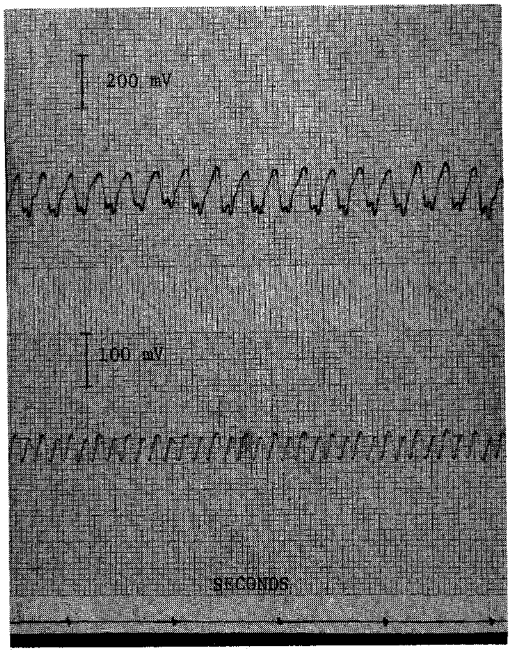

Figure 2. Record of respiratory movement of an intact rabbit.

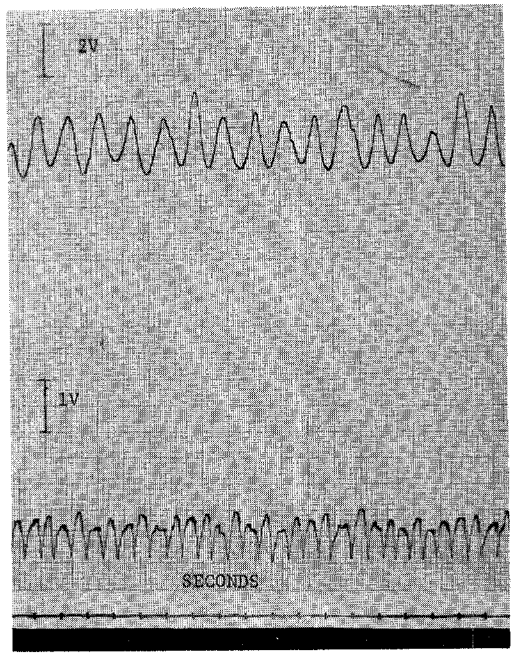

Figure 3. Respiratory measurement of a seated human subject breathing at 51 times a minute.