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Noninvasive Microwave Measurement of Respiration

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Abstract—A microwave technique for measuring respiratory movements of man and animal is described. The technique is noncontacting and is based on the scattering of continuous wave radiation. Preliminary results are shown for both animal and man, indicating the usefulness of the procedure.

INTRODUCTION

Except for diathermy, microwave devices are rarely seen in any clinical setting. This is in sharp contrast to optical and acoustic radiation which have long been recognized as valuable tools in biology and medicine. The use of microwave instruments in the clinic deserves more attention now that many aspects of microwave interaction with the human body are sufficiently understood. Dielectric constant measurements at microwave frequencies, for example, have recently been demonstrated useful in determining the degree of pulmonary emphysema in post mortem analysis by measuring the dielectric properties of dried portions of the lung [1]. Microwave heating of body tissue is currently applied in laboratory experiments to aid in the treatment of animal tumors by chemotherapeutic drugs [2].

In this letter, we present some preliminary results using microwave radiation to measure the respiratory movements of man and animals. Microwave radiation from an X-band standard gain horn is directed toward the upper torso of the subject and the reflection from the chest is detected and compared to the transmitted wave, 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

Microwave energy is derived from an X-band sweep oscillator (Fig. 1) which has a maximum output of 10 mW. In the experiment, 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 attenuator and a 20-dB directional coupler before being radiated through a rectangular horn. Upon incidence on the subject, the microwave signal was 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 was a voltage whose frequency corresponded to the rate of respiration. The outputs from the microwave respiration monitor was capacitively coupled to an oscilloscope and recorded using a strip chart recorder.

RESULTS AND CONCLUSIONS

A 5.1-kg albino rabbit was the subject of one series of experiments in which it was confined to a cardboard box but not anesthetized. The distance between the horn radiator and the rabbit was approximately

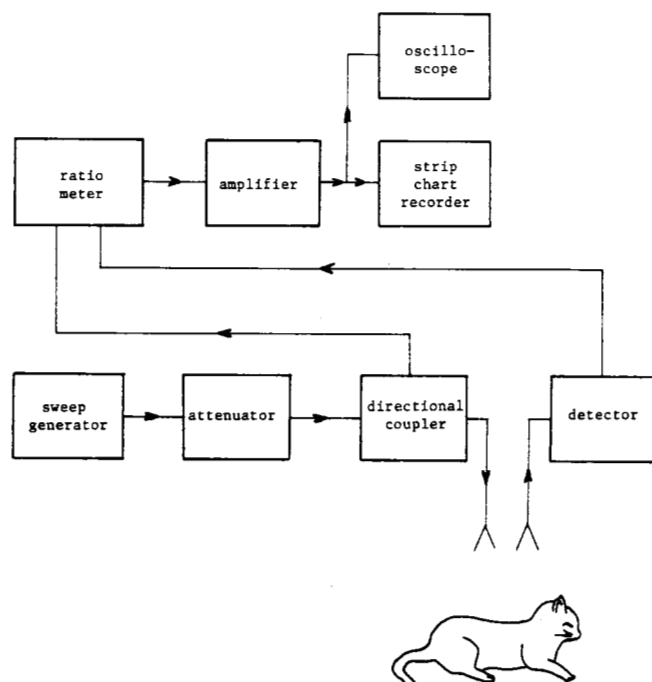


Fig. 1. Experimental setup of noncontact microwave respiration measurement.

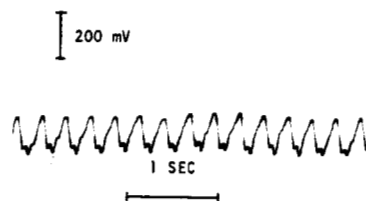


Fig. 2. Microwave measurement of respiratory movement of intact (unanesthetized) rabbit.

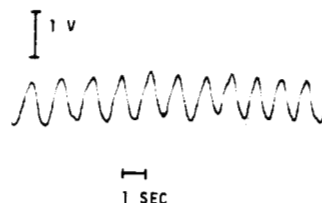


Fig. 3. Microwave respiratory measurement for seated human subject breathing at 47 times per minute.

30 cm. The receiving horn may be 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 Fig. 2. The results for a seated human subject breathing deliberately at approximately 47 times a minute is shown in Fig. 3. The distance between the subject and the radiator was again 30 cm.

It can be seen from these examples that the technique is very useful for respiration measurements. 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.

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