MICROWAVE DOPPLER TRANSDUCER FOR CONTACTLESS CARDIORESPIRATORY MONITORING*

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One presents the results of a study concerning the use of microwave Doppler transducer for contact-less detection of cardiorespiratory activity. The main element of the installation is a microwave Doppler transducer. The Doppler signal resulting from the movement of the anatomical structures is a complex one. The experimental setup also includes an electrocardiograph, a photopletismograph and a pneumatic sensor attached to the thorax to detect breathing motions. At the same time, two types of breathing were identified: the thoracic and the abdominal ones. A good correlation was noticed between the ECG signal and the Doppler signal.

Key words: microwaves Doppler transducer, contact less detection, cardio-respiratory activity.

INTRODUCTION

In the cardiorespiratory monitoring is interesting in a number of situations, the most interesting being in the case of the patients under intensive care, the patients that were given sedatives which can result in a diminished reflexes the new born babies, etc. At present, the cardiorespiratory activity is monitored by the direct contact of the patient with the respiration sensors using the tensiometric marks, capacitive sensors of motion, pulse, or the electrodes that detects the heart bioelectric activity [1]. The problem consists in detecting the cardiorespiratory activity by means of a microwaves Doppler detector of motion, which should permit the detection without a intimate contact with the patient. Another problem is to set apart the signals due to the cardiac activity from the signals produced by the respiration activity.

MATERIALS AND METHODS

The microwave transducer makes use of the Doppler effect in the microwave range [2] in order to detect the complex motion of the torax anatomic

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structures as the result of the cardiorespiration activity. In order to study the possibility of using a Doppler transducer, the experimental setup presented in Fig. 1 was used.

The main element of the installation consists of the Doppler transducer made of a sender-receiver set coupled to a wave-guide having as load a rectangular horn antenna with an aperture of 100×130 mm. The generator frequency is 8 GHz. The very low frequency Doppler signal resulting from the detection's amplified (at a gain of 40 dB) and then applied to a DAS 1601 Keithley data acquisition system. The subject is set horizontally lain down and with the horn antenna directed perpendicularly toward his body, at a distance of 10 cm from this skin surface. The bioelectric heart activity is recorded by means of the electronic module for ECG made with the AD 640 (Burr Brown) integrated circuit, and the used electrodes are made of silver. The resulting ECG signal is applied at the DAS 1601 data acquisition system input. In order to register the pulse, a photopletismograph was fixed at a finger. A pressure transducer connected to a balloon fastened with a belt on the thorax circumference records the breathing activity. This represents the fourth measuring channel and permits to obtain information about the breathing amplitude and frequency as well as to record the apnea condition after the expiration and inspiration. The pressure transducer is connected to a digital micromanometer, which also delivers an analog signal applied to the DAS 1601 data acquisition system.

The utilization of high frequency electromagnetic waves implies certain difficulties connected to the electromagnetic waves propagates through the biological structures, to the complex phenomena of reflection, refraction, absorption, diffusion and interference that can occur the skin depth in certain tissues, a different e.m. field absorption at the input and output of the wave from the human body. In order to ensure a minimum level even below the one permitted by standards for the electromagnetic. field intensity, one has to use generators of small power, of the order of a number of milliwats [3]. We preferred to use a frequency of some GHz, given the fact that the phenomena specific the microwaves propagation are more obvious at this frequencies; stil another reason is determined by the simplicity of the Doppler transducer at these frequencies. At this frequencies the skin depth in muscles, lung and blood is of some millimeters, reaching 2–9 mm in fat [4].

RESULTS

Due to these complex phenomena, it is quite difficult to state precisely which of the anatomical structures contribute the most in rendering evident the cardiac activity. What concerns the respiratory activity, it is quite easily to detect the Doppler signal having a relatively high amplitude. From Fig. 2 one can notice a good correlation between the complex Doppler signal and the signal due to the respiratory activity. The signal given by the manometer follows the respiratory activity, its maximum values corresponding to the thorax outward motion by air inspiration and its minimum values corresponding to the reverse thorax motion. As one ca see, the corresponding Doppler signal quickly changes its phase by 1800. Taking into account the relatively small (4 mm) skin depth within the tissue, one can state the respiratory activity is only detected due to the motion of the thorax outer layers. Concerning the cardiac activity, the Doppler signal is move complex, being generated on the one side by the modification in size and position of certain anatomical structures as parts of the cardiac circuit, and on the other side by the changing in the tissues electric properties due to the motion and changing blood irrigation during a cardiac cycle. The electric signals picked up from a patient by the ECG electrodes or by electronic circuits are processed by means of the data acquisition system DAS 1601. With the view to determine the most adequate zones for detecting the cardiac activity, records have been made in different thorax zone, by placing the horn antenna in different positions, as shown by Fig. 3.

DISCUSSION

The records from Fig. 3 were made the apnea condition after inspiration. The diagrams present the signals picked-up by the photopletismograph as a reference signal, and the Doppler signals corresponding to the zone against the thorax. In most of the diagrams, one can remark a time alteration of the amplitude of the signal pick-up by the photopletismograph; this is the result of the apnea state installed at the beginning of every measurement. From the A, B… L, diagrams one can remark variable amplitude of the Doppler signal depending on the transducer's position as related to the thorax. As one can see, the highest signal amplitude is in the zones E, F, H zones meaning the region were the heart is placed, due to the heart's contraction motions and to the larger blood volume pumped through the organism by means of the aortic artery. At the same time increased signal values are recorded in the K zone corresponding to the direction of the descending thoracic abdominal aorta.

Fig. 4 shows the results of cross correlation between ECG signal, photopletismograph and Doppler signal coresponding to cardiac activity. It is necessary filtration before using Doppler signal for patient cardiorespiratory monitoring. Fig. 5 shows Doppler signal due to cardiac activity. By filtering we can extract only signal corresponding to fundamental frequence. Filtering signal as used to determine cardiac signal frecquency in concordance with bloc diagram from Fig. 6.

Complex Doppler signal is used for measuring cardiac is used for measuring cardiac activity. For this, the signal is amplified and filtered adequate to extract fundamental frequency. It is applied a filtered signal to a frequencemeter or periodmeter. Measured value is seen on a display. It can be used a programable frequency discriminator which is able to detect variations and command an alarm for abnormal cardiac frequencies. Doppler signal has the same periodicity as cardiac activity. Its amplitude varies for a cardiac cycle due to surface movement of anatomic structures.

CONCLUSIONS

The experimental results confirm the possibility to use a microwave Doppler detector of motion for detection, recording and explaining the signals produced by the cardio-respiratory. The method permits to detect the apnea condition, the breathing frequency, as well as the heart activity. The radiant energy is much below the admitted limits; the energy density at the horn antenna output is 0.03 mW/cm^2. One can also remark a good correlation between the complex Doppler signal and the ECG signal, the breathing and the pulse photo-electric transducer.

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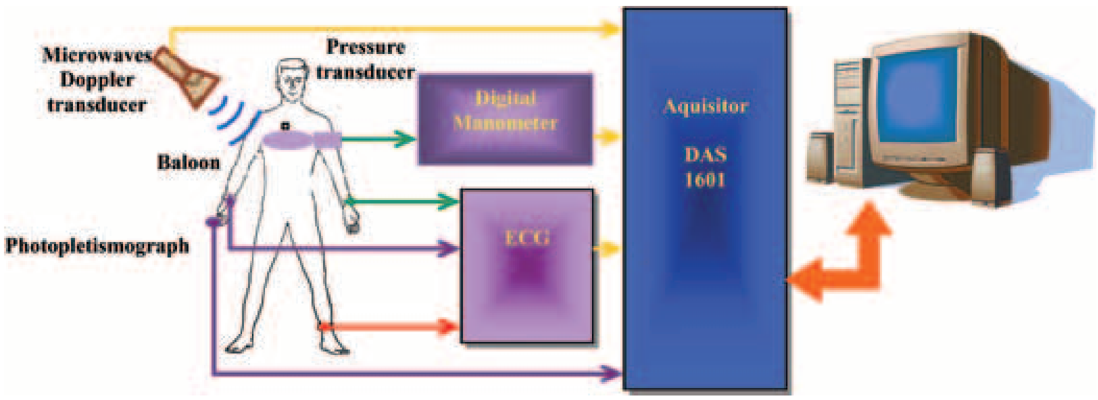

Fig. 1 – Experimental setup for the study of cardiorespiratory activity using a microwave Doppler transducer.

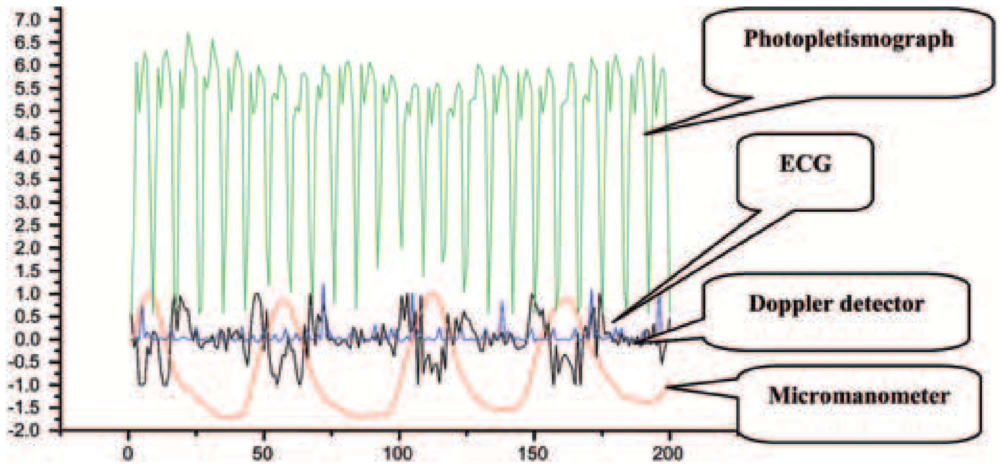

Fig. 2 – Cardio-respiratory activity monitored by ECG, Doppler effect, thorax transducer and photopletismograph.

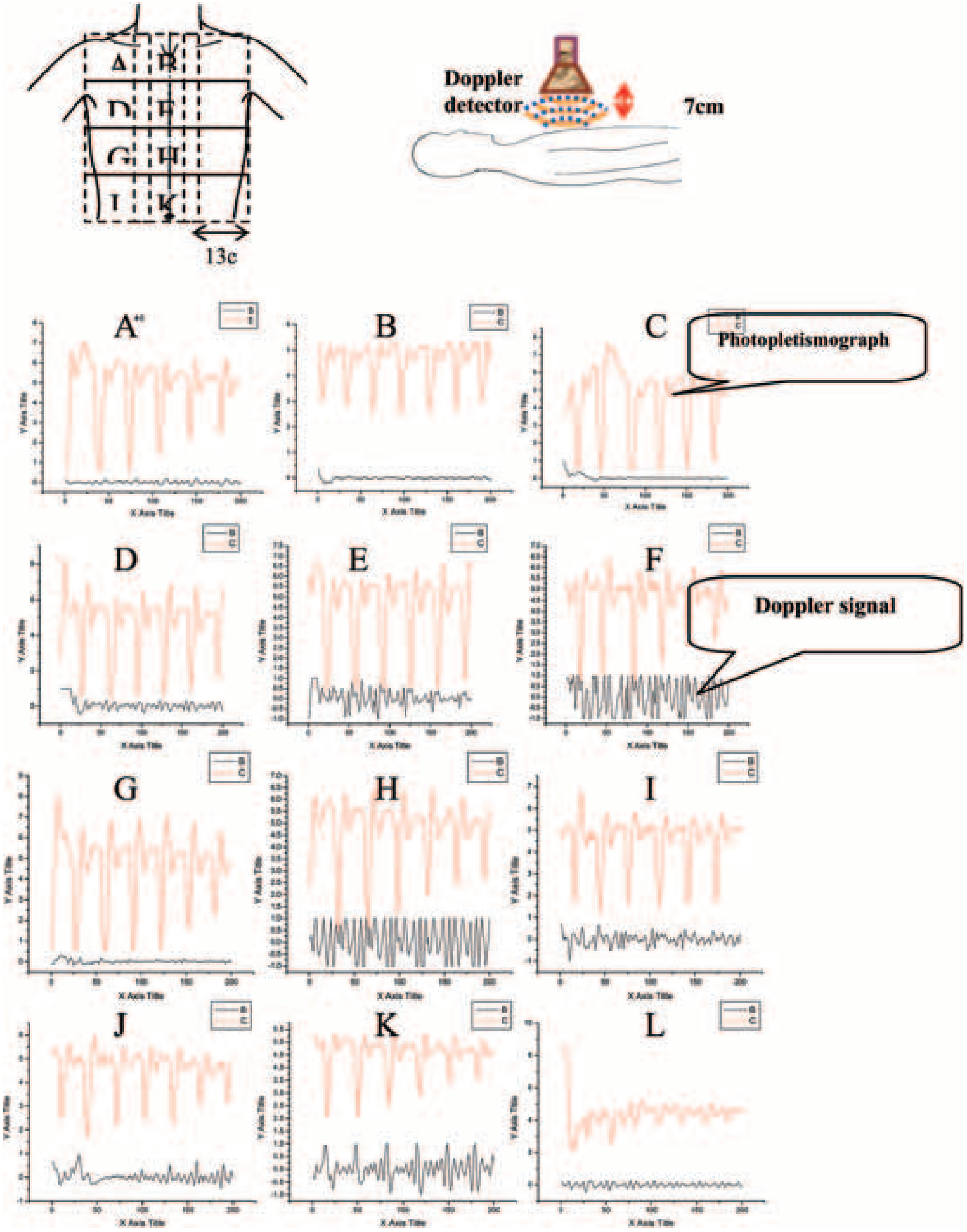

Fig. 3 – Doppler microwaves map-signal generated by the cardiac activity.

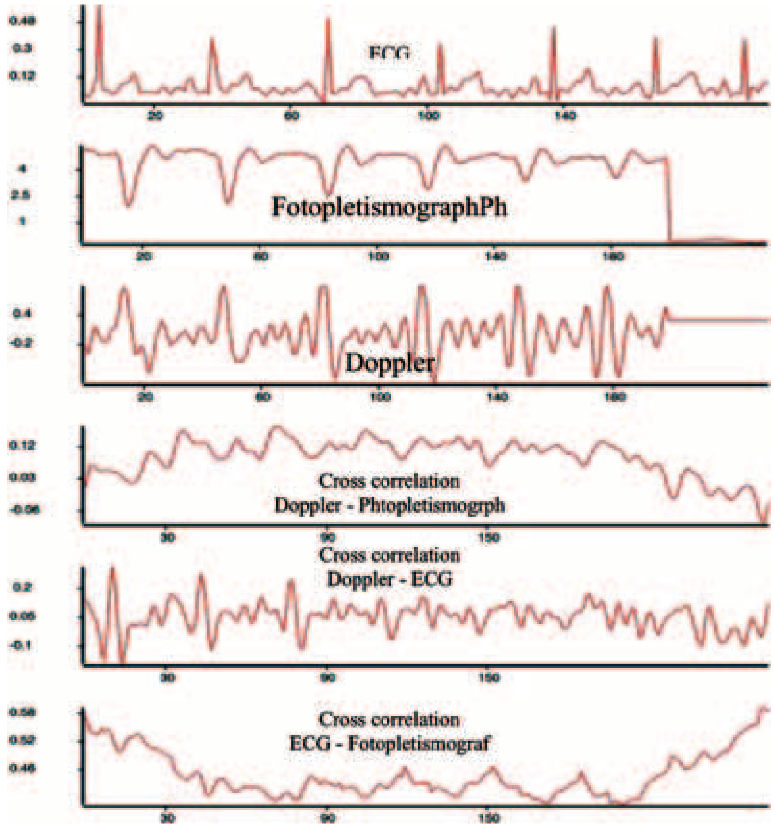

Fig. 4 – Cross correlation function between ECG, photopletysmograph and Doppler.

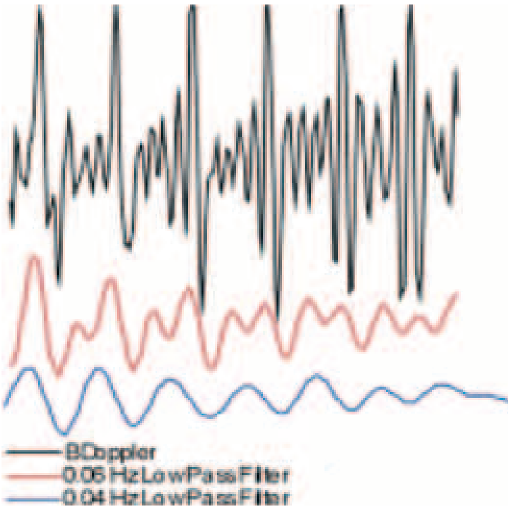

Fig. 5 – Filtered Doppler signals.

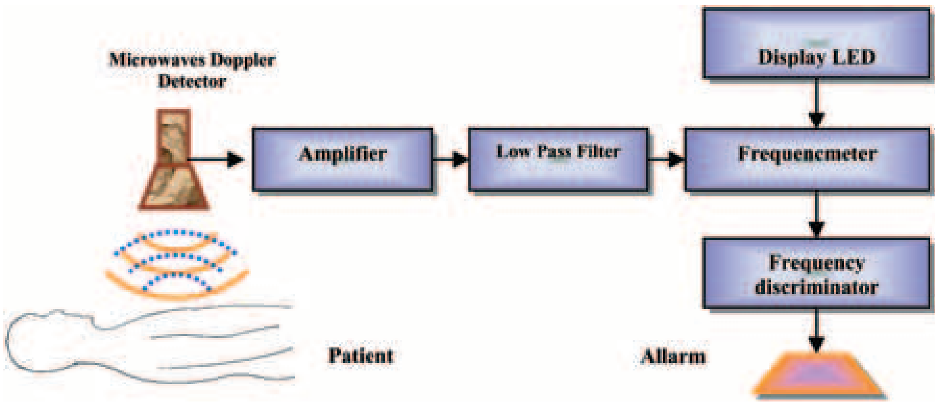

Fig. 6 – Bloc diagram for patient monitoring devices.