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ULTRA-WIDEBAND (UWB) RADAR FOR THE REMOTE MEASURING OF MAIN PARAMETERS OF PATIENT'S VITAL ACTIVITY

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The capability of UWB radar usage in medicine the for remote measuring of patient's heart activity and respiration is considered. The measuring method is described and practical results of the tests are cited. The possibility of the radar implementation in some other fields is shown.

1. Introduction

The UWB radar represented in the report serves for the non-contact measuring of parameters of person's respiration and heart activity. It is appointed for work at clinics and for home use. The permanent monitoring of patients with heart troubles or cardio diseased patients is executed and statistics of major parameters of person's vital activity is accumulated with its help.

UWB radar permits to carry out the radar detection of the people behind different obstacles (walls, vegetation and so on) due to their motion or the motion of their thorax and heartbeat in the case of motionless state. Thus, it can be used by rescue services for the search of people under building wreckages and snow-slides. Besides, this radar can be used by law-enforcement services for the search of criminals hiding under different covers.

2. The Measuring Method and Its Advantages

The non-contact measuring method of the frequency of person's respiration and cardiac contractions is founded on the measuring of the acceleration of person's heart and thorax motion.

The measuring is executed by the radar method. The ability of electromagnetic waves to partially reflect from the boundary between two media and penetrate through it is in the base of this method.

UWB signal with duration between 0.2 and 1 nanosecond is chosen to transmit electromagnetic energy. Such signal permits to:

1. enlarge the resolution ability of radar, to measure parameters of heart and thorax motion separately;
2. diminish the minimal distance at which the measurements are executed;
3. decrease the spectral density of the radiated signal power and the electromagnetic radiation level irradiating the physician, patient, hospital equipment;
4. diminish the sizes of device;
5. increase the device protection from outdoor interference and enhance the reliability of measurements.

3. The Description of the Non-Contact Measuring Method

The essence of the method is like this.

The radar transmitter generates the sequence of short pulses with the leading-edge duration of 250 picoseconds order (Fig. 1) which excite antenna and are radiated in space (the radiated pulse and its spectrum are shown in Fig. 2,3).

The pulse repetition cycle equals

$$T = d / c ,$$

where d is spatial distance between pulses, c is the velocity of light (m/s). The pulse repetition frequency equals

$$f = 1 / T = c / d .$$

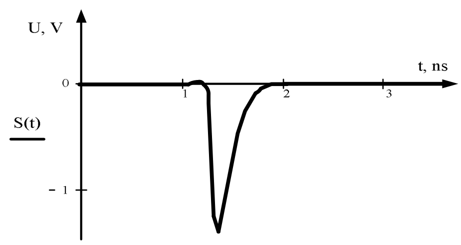


Fig. 1. *The transmitter video pulse*

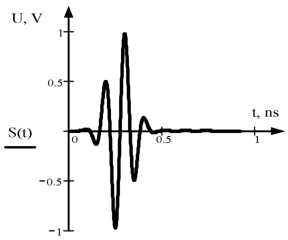


Fig. 2. *The pulse radiated by antenna*

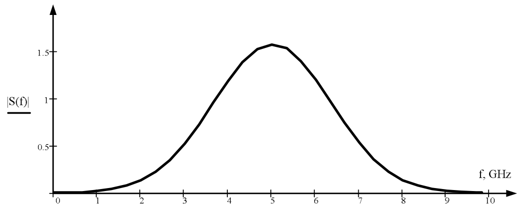


Fig. 3. *Amplitude-frequency spectrum of the radiated signal*

This pulse sequence is reflected from the object. The pulse repetition cycle remains invariable if the object is motionless.

Under the motion of object by the harmonic law the velocity of its motion varies as

$$V = V_s \sin(\omega_s t).$$

As a result, the spatial distance between the pulses is

$$d_s = d - TV_s \sin(\omega_s t),$$

the pulse repetition cycle

$$T_s = \frac{d - TV_s \sin(\omega_s t)}{c},$$

and the pulse repetition frequency

$$f_s = \frac{1}{T_s} = \frac{c}{d - TV_s \sin(\omega_s t)} = \frac{f}{1 - \dfrac{V_s \sin(\omega_s t)}{c}}.$$

Thus, we obtain the frequency-modulated signal with non-linear dependence of the signal frequency on the velocity of object's motion. Time dependence of the relative variation of the repetition frequency of pulses reflected from the heart is shown in Fig. 4.

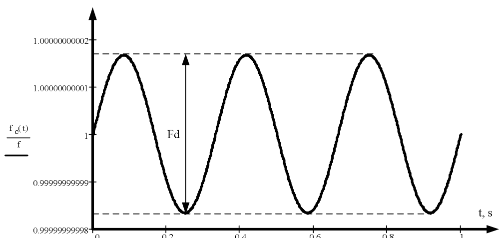


Fig. 4. *The relative variation of the repetition frequency of pulses reflected from the heart under Vs = 0.005 m/s*

The modulated sequence of pulses carrying the information on the parameters and character of the examined organs is put to initial processing in the radar transmitter, digitized and input into computer for further processing and the selection of the needed information.

4. The Block Scheme of UWB Radar

A simplified block scheme of the radar is represented in Fig. 5

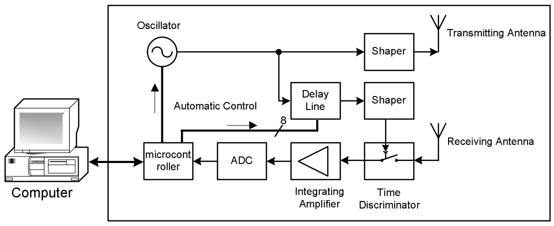


Fig. 5. *A simplified block scheme of UWB radar*

The oscillator "Oscillator" with controlled pulse repetition frequency produces rectangular pulses with frequency of 0.05 – 30 MHz. These pulses enter the short pulse shaper "Shaper" of a transmitter and the delay line "Delay Line" of the transmitter gating unit.

The transmitter consists of the short pulse shaper "Shaper". The pulses from the "Shaper" output are fed to "Transmitting Antenna" and make the shock excitation of it. "Transmitting Antenna" radiates the short radio-frequency pulses (short r) (Fig.2).

The radiated electromagnetic field pulses are reflected from the moving surfaces of the thorax and heart of the examined or detected person. Here the modulation of pulse repetition frequency arises (Fig.4). The modulation percentage depends on the velocity and amplitude of person's thorax and heart motion.

The radar works in the conditions of high level of passive noise from the signals reflected from walls and stationary objects; which have large amplitudes and distort the useful signal (Fig.6).

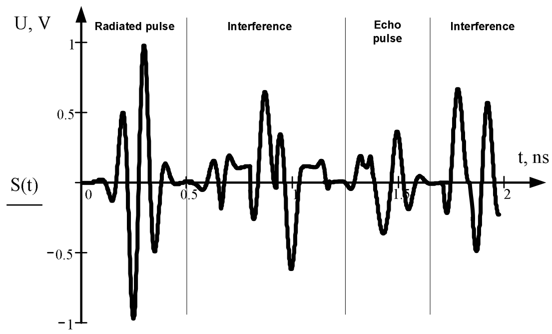
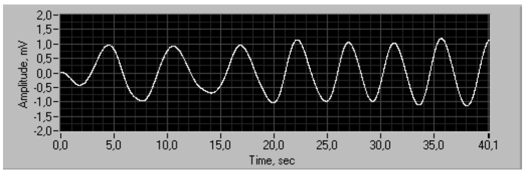
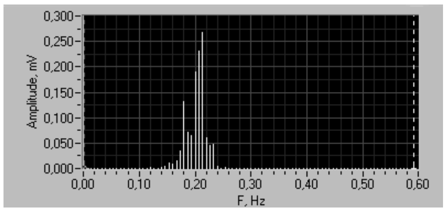
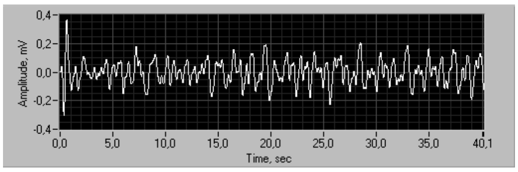
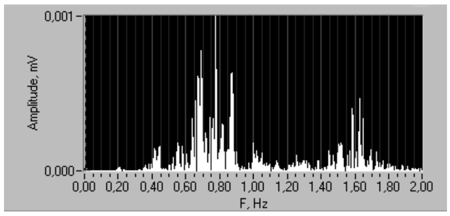
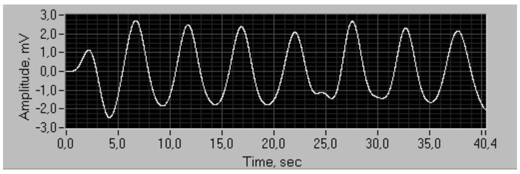
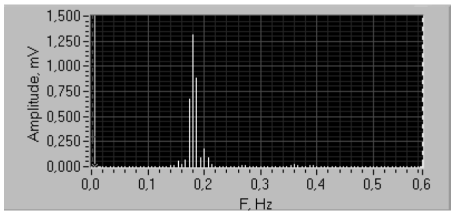
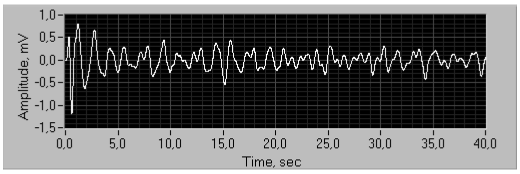
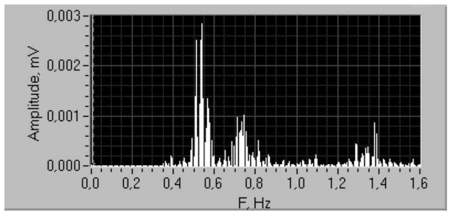


Fig. 6. *Time diagram of the received electromagnetic field*

Table 1. *The results of two measuring cycles*

		Time	Frequency
First Man	Respiration		
	Heart Activities		
Second Man	Respiration		
	Heart Activities		

Time slots, opening the receiver at the moment of the input of the signal reflected from the object at distance defined, are formed in the receiving path to eliminate interfering pulses. This task in the radar design is executed by the gated time discriminator "Time Discriminator. It consists of fast-acting electronic switches. The switching time is of 200-300 picoseconds order. The switches connect the receiving antenna to UWB amplifier at the moments of signals' input. These moments are defined by delay magnitude of control signal at software-controlled delay line "Delay Line". All the rest time the receiver is shut. The signals received at time slots are detected and amplified in integrating amplifier and the signal carrying the data on person's thorax and heart motion is selected at its output.

The gating unit consists of the software-controlled delay line "Delay Line" and the shaper of short pulse "Shaper". Time delay, set up by the microprocessor-controlled unit "microcontroller", defines the distance to a patient. Time constant of integration of "Integrating Amplifier" is chosen depending on the bandwidth of the desired signal (dynamic characteristics of the motion of object examined). Under detection of person and measuring of parameters of his vital activity the bandwidth of desired signal is near 400-500 Hz, which corresponds to accumulation of 10~30 thousand of pulses approximately. The accumulation permits to decrease the average radiated power of the transmitter and increase the signal-to-noise ratio at the input of amplifier.

The selected and amplified low-frequency signal, which is proportional to respiration frequency and heart contraction, enters analog-digital converter "ADC". The microprocessor-controlled unit "microcontroller" directs the work of the radar by the given algorithms, monitors the state of major units and modules and provides data output for further digital processing in computer. The selection of moving targets, fast Fourier transform and the digital filtration are software-programmed.

Physically the radar is built up as the modular hardware. All the modules are shielded to eliminate each other interference. The antennas connection is carried out directly to the output connectors of the radar receiver and transmitter.

5. Implementation

The radar prototype is created and tested with respect to the principles mentioned. The major specifications of the prototype are given in the table 2.

Table 2. *The major specifications of the prototype*

Item	Specifications
Antenna pattern (H-plane)	360° with dipole antenna
Central frequency	~ 5 GHz
Average radiated power	~ 0.04 μW
Receiver gate duration	~ 250 picoseconds
Delay stability range	Limitation on temperature dependence of RC component's parameters
Detection range	~ 0.06 – 5 m
Motion pass band	~ 0.16 – 5 Hz, Doppler-like signature
Receiver gain	95 dB

The form of the transmitter and receiver on antenna boards are shown in Fig. 7.

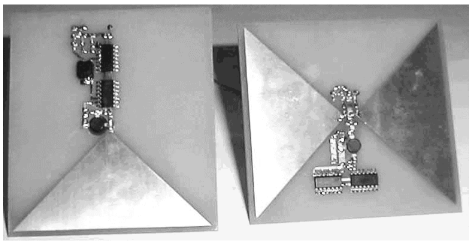


Fig. 7. *The form of the preliminary prototype*

The measuring of person's heart activity and respiration is executed using the radar prototype. The results of two measuring cycles are presented in table 1. The temporal structure of the processes of respiration and heart activity is shown in the left-hand figures. The gain-frequency spectrums of these processes are shown in the right-hand figures.

The obtained oscillograms and spectrograms enable to perform objective estimates of the parameters of person's vital activity. The further clinical analysis of the results is carried out in an automatic mode.

6. Conclusion

The developed radar prototype and the results of its tests have confirmed the capability and perspectiveness of the UWB signals applications in medical analysis, law-enforcement services under extreme situations, and for other applications.

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СВЕРХШИРОКОПОЛОСНЫЕ РАДАРЫ ДЛЯ ДИСТАНЦИОННОГО ИЗМЕРЕНИЯ ОСНОВНЫХ ЖИЗНЕННЫХ ПОКАЗАТЕЛЕЙ ПАЦИЕНТОВ

И.Я. Иммореев, С.В. Самков

Рассматривается возможность использования широкополосного радара в медицине для дистанционного измерения сердечной и дыхательной деятельности пациентов. Описан метод измерений и приведены практические результаты исследований.

НАДШИРОКОСМУГОВІ РАДАРИ ДЛЯ ДИСТАНЦІЙНОГО ВИМІРЮВАННЯ ОСНОВНИХ ЖИТТЄВИХ ПОКАЗНИКІВ ПАЦІЄНТІВ

І.Я. Імморєєв, С.В. Самков

Розглянуто можливість використання широкосмугового радара в медицині для дистанційного вимірювання серцевої та дихальної діяльності пацієнтів. Описано метод вимірювань та наведено практичні результати досліджень.