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SWITCHED ULTRAWIDEBAND ANTENNA ARRAY FOR RADIO TOMOGRAPHY

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The characteristics of the ultrawideband (UWB) timed antenna array developed by the authors are described. The efficiency of the system is confirmed by experiments processed with the use of focusing and aperture synthesis methods. Technical solutions used in this work allow us to proceed to the development of the UWB radio tomograph operating in real time.

Keywords: radio tomography, UWB sensing, aperture synthesis, radiation focusing.

INTRODUCTION

Nowadays, in connection with increasing threat of terrorism and frequent local conflicts, an urgent need arises in the development of domestic contactless radio systems of remote detection of explosives and weapon disguised. These systems must detect with high degree of probability and visualize forbidden objects hidden under clothes, in hand luggage, and in various engineering designs [1, 2]. The induction methods widely used in practice are very efficient for detection of metal objects, but do not allow dielectric enclosures to be recognized. X-ray systems partly solve this problem, but they are far from being harmless to living beings. In addition, the application of x-ray radiation calls for bilateral access to the object being sensed that is not always possible. Radio waves are practically completely harmless. Ultrawideband short-range radars allow all problems enumerated above to be solved. They can also find application during special actions for detection and identification of people hidden behind walls of buildings. The UWB radars allow not only a person to be detected, but also the parameters of his/her physiological state to be determined [3].

The application of UWB radiation in radars intended for radio vision imposes rigid requirements on such important parameters of devices used in these systems as speed of response and resolution. In the present work, the characteristics of the UWB timed antenna array created by the authors are described. The efficiency of the antenna array is confirmed by the results of experiments processed by focusing and aperture synthesis methods. The technical solutions obtained in this work allow us to proceed to the development of the UWB radio tomograph operating in real time.

TIMED ANTENNA ARRAY

The antenna array comprising 16 receiving and 6 transmitting elements optimized for reception and transmission of the UWB electromagnetic pulse with duration of 0.2 ns was developed to solve the above-formulated problem (Fig. 1). A screen was located between the transmitting and receiving elements to reduce the amplitude of direct pulses propagating from the transmitter to the receiver.

The transmitter design was suggested by Yu. I. Buyanov, Associate Professor of Radio Physics Department. Its indisputable advantage is 6-fold overlap of the transmission band. Figure 2 shows the measured voltage standing wave

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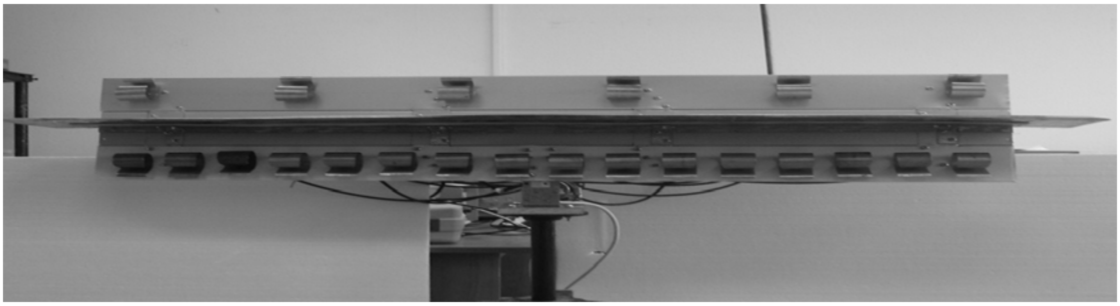

Fig. 1. Switched UWB antenna array.

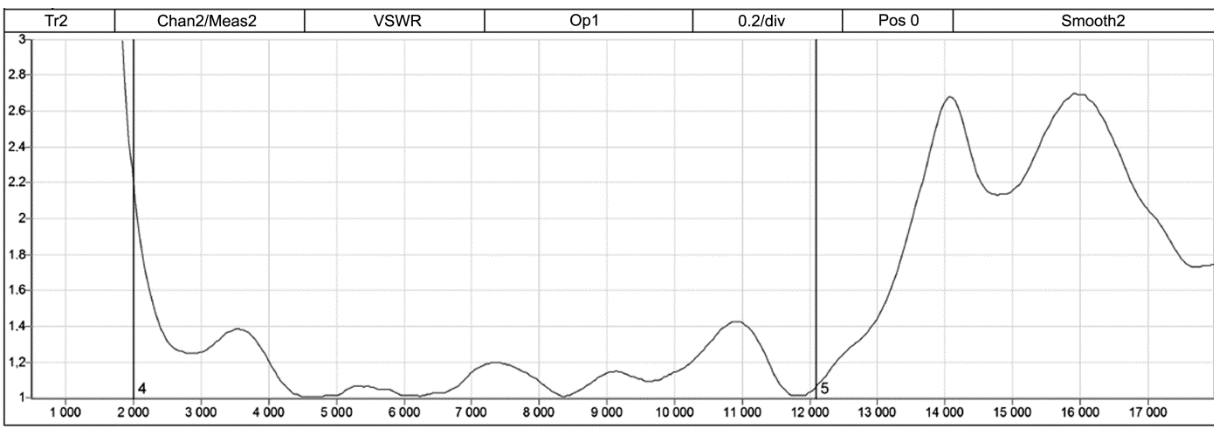

Fig. 2. VSWR of antenna array element.

ratio (VSWR) of one of the transmitters. Measurements were performed with an R2M-18 scalar circuit analyzer (SPF "MIKRAN").

As can be seen from Fig. 1, the VSWR of the developed antenna is less than 2 for frequencies in the range from 2 to 13.5 GHz, which completely overlaps the frequency range of the UWB sensing pulse.

The radiation pattern of each transmitter in the horizontal plane is symmetric, and its beam width is about 90° at a level of 0.7. In the vertical plane, the pattern of the array element is tilted due to antenna asymmetry. Figure 3 below shows radiation patterns in the vertical plane at the indicated frequencies near the maximum of the UWB pulse spectrum. Thus, the array elements are well matched and have stable radiation patterns in both planes of the examined frequency range.

BLOCK OF SWITCHING CHANNELS OF THE ANTENNA ARRAY

The block of switching channels of the antenna array was built around two 8-channel and one 6-channel mechanical UWB switchers (Dow-Key Microwave Corp.) that overlap the frequency range from 0 to 18 GHz (Fig. 4). Decoupling between channels was 60 dB, and maximum switching time was 15 ms.

A special block was developed to control over the switches. The display panel was on the front of the device, where each light-emitting diode corresponded to the serial number of the switched channel.

Supply sockets, COM port, and power cables that directly control switches were on the rear panel of the device. Channel switching was controlled by a personal computer. To switch the channel, the computer sends a command to a microcontroller which, in turn, by a certain algorithm controls over a set of power switchers. The latter provide timely switching of channels.

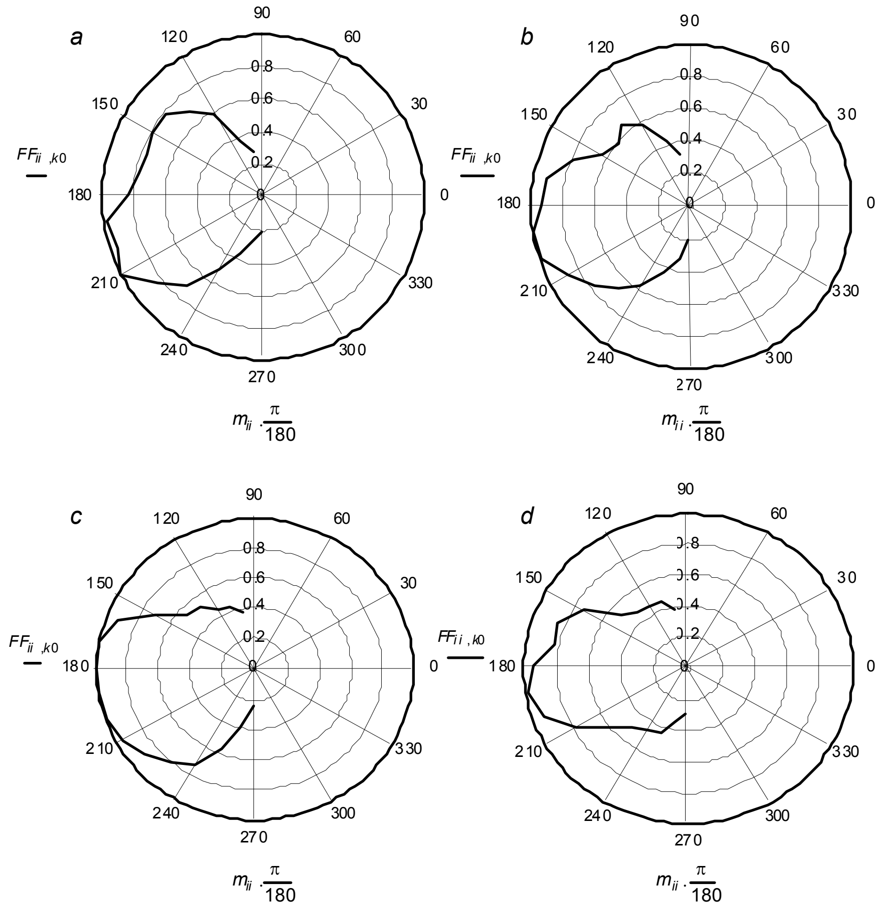

Fig. 3. Radiation pattern at frequencies of 4 (*a*), 5 (*b*), 6 (*c*), and 7 GHz (*d*).

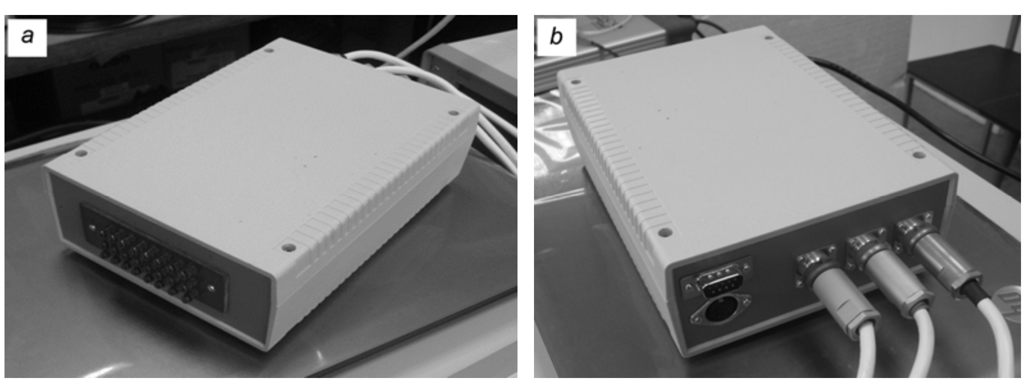

Fig. 4. Block of switching channels.

Figure 5 shows the schematic diagram of channel switching based on an STM32F107 microcontroller.

RG-58 coaxial cables 55 cm long were used in the system as transmission lines. The transmission coefficient (TC) of the lines is shown in Fig. 6.

As can be seen from Fig. 6, attenuation for frequencies from 2 to 12 GHz is –1.2 dB.

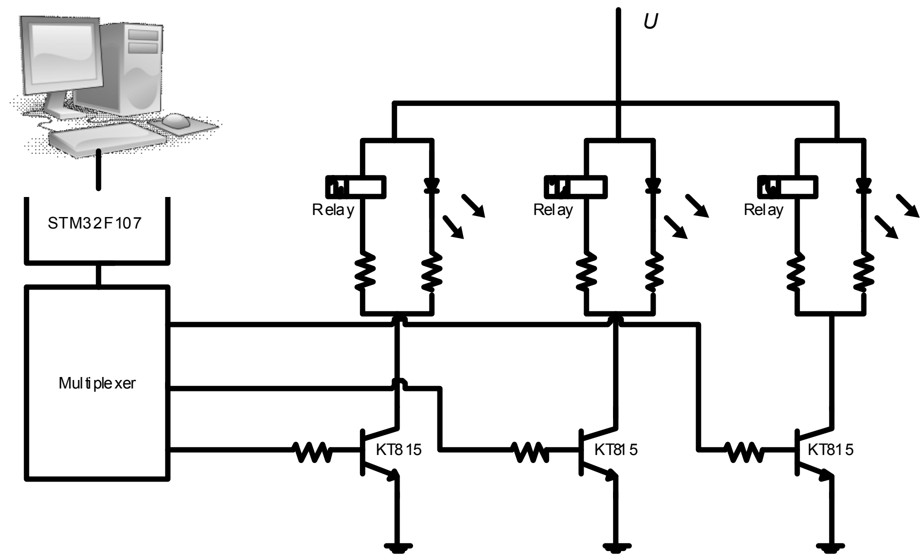

Fig. 5. Schematic diagram of channel switching.

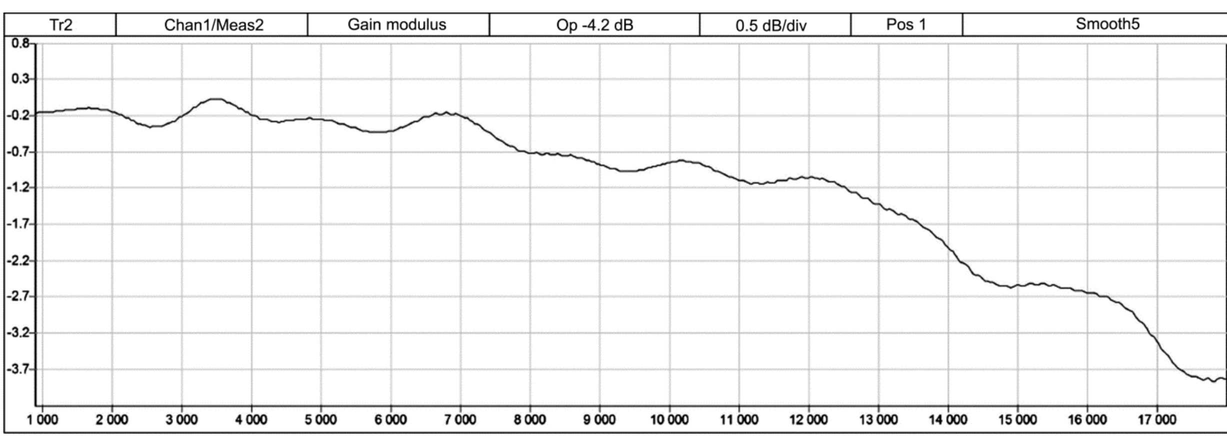

Fig. 6. TC of the transmission line 55 cm long.

EXPERIMENTAL INVESTIGATIONS

The important parameters of the developed antenna array, such as speed of response and resolution, were estimated experimentally.

The TMG200020R01 generator of bipolar pulses having amplitude of ±15 V with accuracy of $\pm 0.1U_{max}$ and duration of 200 ps at a level of 0.1 of maximum and shape close to a sinusoid period was used as a pulse source. The pulse repetition frequency was 100 kHz. An AKIP 4112 two-channel stroboscopic digital oscilloscope operating in the range from 0 to 12 GHz was used to register and to measure ultrawideband pulses.

Our experiment demonstrated that to interrogate the entire array, on average, 0.88 s was required. This time could be reduced to 0.5 s by means of optimization of some parameters.

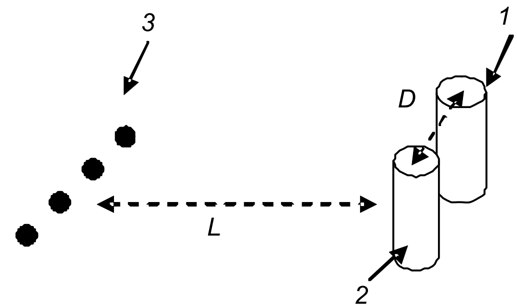

Fig. 7. Experimental configuration comprising metal cylinders *1* and *2* with diameters of 3 cm and timed antenna array *3*.

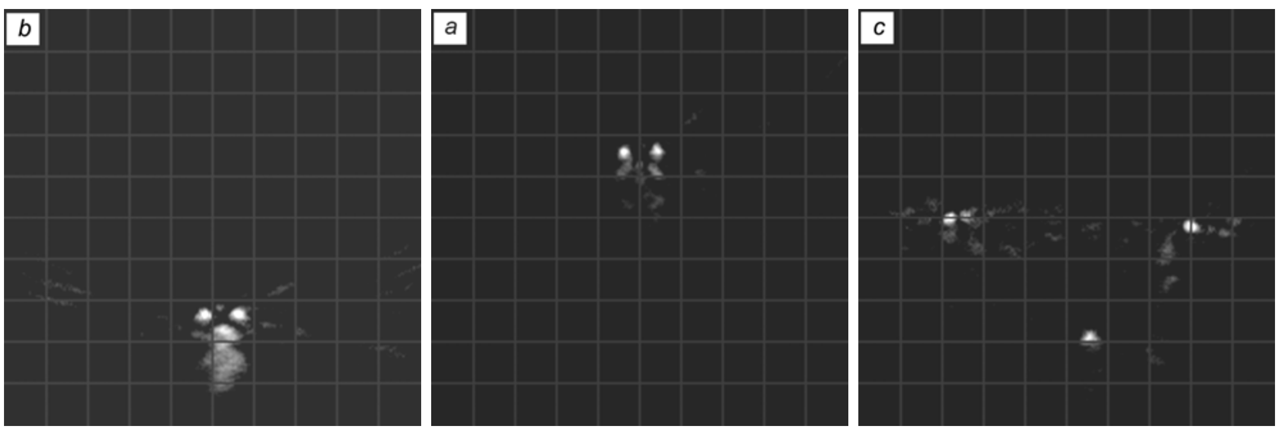

Fig. 8. Radio image of test objects for $L = 60$ cm and $D = 6$ cm.

To estimate the spatial resolution, a series of experiments on sensing by UWB radiation of several metal cylinders 3 cm in diameter was performed. UWB pulses reflected from cylinders placed at distances of 60 and 100 cm and spaced at different distances from each other were registered. The experimental configuration is shown in Fig. 7.

The technology of data processing was based on methods of aperture synthesis with mathematical focusing [1]. Figure 8 shows radio images of the test objects. The size of each image grid is 10 cm. Figure 8*a* shows the radio image of two cylinders located at distances $L = 60$ cm from the antenna array. The distance between the cylinder centers was $D = 9$ cm. Analogous results for $L = 100$ cm are shown in Fig. 8*b*. In this case, the secondary signal caused by re-reflection between metal cylinders can be seen. As a result of re-reflection, a false object is seen on the radio image. However, its intensity is less than that of actual objects. Figure 8*c* shows the radio image of three cylinders. Two of them were at the distance $L = 80$ cm, and the third cylinder was at the distance $L = 110$ cm.

Thus, the position of test objects was determined reliably. The focusing technique provides high radio image quality and low level of artifacts. The estimated resolution was no worse than 4 cm for a distance of 1 m and of the order of 2 cm for a distance of 60 cm.

CONCLUSIONS

A significant amount of work has been done to develop the UWB antenna array. Its application for radio vision system will allow problems of detecting hidden objects to be solved in real time. Due to the complex of technical solutions on optimization of channel switching, the scanning time did not exceed 1 s, and the radio image resolution reached 2–4 cm for distances up to 1 m. Finally, the antenna array together with the methods of mathematical focusing and algorithms of received signal processing developed by the authors has allowed us to start the development of the operating model of a radio tomograph.

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