Invited paper

Features of Formation of Radar-Tracking and Optical Images in a Mobile Test Stand of Radio-Vision Systems of a Car

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Abstract—In the report the features of formation of radar images (RI) and optical images (OI) in the mobile test stand of radio-vision systems (RVS) of a car are presented. The radio-vision system of a car (CRVS) of the millimeter-wavelength with frequency modulation is considered. Features of formation and processing of the radar-tracking image in CRVS are discussed, in particular: the sizes of the image, system of coordinates, primary and secondary processing of RI, requirements for speeds of transfer of figures in real time of processing, for subsystem of display of RI and synchronization. The structure of the mobile test stand of CRVS is described. This stand consists of: CRVS, a video camera, the module of formation, recording and display of RI and of optical images, the module of control of a stand, the power supply unit. Features of formation and display OI are considered, in particular: the coordination of scale and shortening of images, creation of time synchronization at display and records of OI, and questions of synchronous fusion of RI and OI also.

Keywords*—*features of formation and fusion of radar and optical images, mobile test stand, radar image, radio-vision system of a car.

1. Introduction

The development of motor industry in the world constantly increases and the intensity and density of transport movement on road increase also. As a result quantity of road and transport incidents (road accident) increases also.

The reasons of road accident are various. So, according to American Agency NHTSA (National Highway Traffic Safety Administration), besides malfunction of a vehicle, 68% of road accidents are connected with a carelessness and insufficient knowledge of the driver of a road situation. Thus, insufficient knowledge of the driver is in direct dependence on conditions of optical visibility such as: light exposure of road and a roadside, visibility of a marking and indexes, a degree of windscreens impurity cabins, presence in air of a fog, a snow, a rain, a dust, a smoke and other preventing factors.

In works [1]–[3] it is shown, that the core by the decision of an actual problem of increase of traffic safety of vehicles in conditions of absence or the limited optical visibility is use on the car of the radio-vision system (CRVS). This system is working in millimeter range of wavelengths and does not depend on any weather conditions: a smoke, a dust, etc. The CRVS is the small-sized, all-weather, information-measuring system representing new generation of panoramic radar stations (RS) of the forward review for modern vehicles. This system has not analogues in the world market.

Several years ago the experimental sample of CRVS has been developed by experts of Moscow Aviation Institute (MAI) and produced. This radar is intended for formation radar images (RI) of road conditions in front of a car. The driver in conditions of absence of optical visibility can observe on the screen the indicator in the interior of the automobile an obstacle a border of the road, traffic signs, obstacles and vehicles parked on a roadside within the working range of CRVS in view of dynamics of movement of own automobile also.

2. Features of Formation and Processing of RI

In Fig. 1 the block diagram CRVS designed is presented. The CRVS is constructed as panoramic RS of millimeter-wave length with linear frequency modulation (LFM) of a signal of the transmitter. The antenna of CRVS is a rotating wave-slot-hole antenna array. The antenna of CRVS scans space in front of the car in the set of working sector. The information about conditions of movement in front of the car is incorporated on the receiver output of CRVS in the mixed signal of transmitted and reflected from the purpose of signals. From an output receiver of CRVS the mixed signal transfer on input of analog to digital converter (ADC) – a part of block of digital signal processing (DSP).

The further primary processing of the digitized mixed signal includes following basic stages: digital filtration with application of procedure of decimation; intermediate buffering; formation of information packages and transfer of the generated data files on the operating HOST-computer; fast Fourier transform (FFT) by program methods on a personal computer (PC); addition on RI the demanded service information (a coordinate grid); a conclusion received RI on the screen of the indicator (the monitor of the PC).

One of serious problems which limits wide introduction of CRVS in modern automobiles is the creation of secondary algorithms of processing of RI for formation of the radar image adequate for the driver. In experimental sample of CRVS secondary processing of the information consists in elementary formation on the final radar image of the additional information such as drawing a grid of a range of distances in a mode of real time.

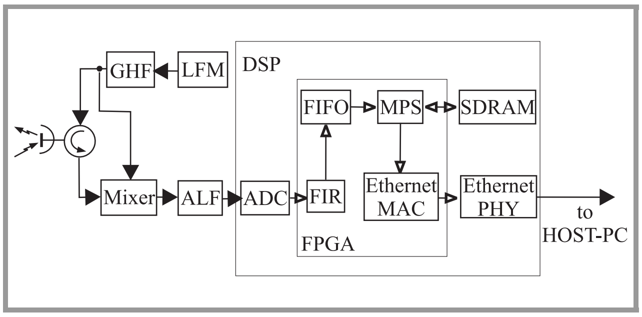

Fig. 1. The block diagram of CRVS. Explanations: GHF – generator of high frequency, ALF – amplifier of low frequency, FIFO – first in first out, FIR – finite impulse response, FPGA – field programmable gate array, MPS – microprocessor system, MAC – media access control, SDRAM – synchronous dynamic random access memory.

However, the part of tasks of secondary processing of RI is solved by developers of CRVS in a model variant on PC only. Among these tasks: definition of a range up to obstacles and taking place vehicles (VC), properly informing the driver about a critical range up to objects of an artificial origin (AO) in lane of VC, and automatic definition of width of road and distances from the automobile with CRVS, up to left and right roadsides also.

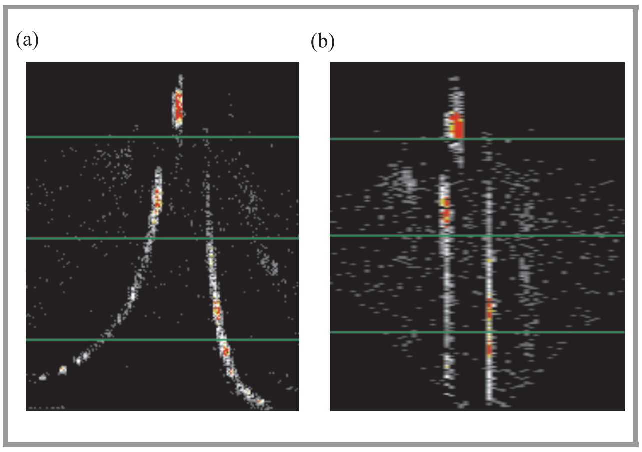

Fig. 2. Radar image in coordinates: (a) range-azimuth; (b) range-range.

In Fig. 2(a) the example of the staff of the radar image which is observed by the driver on the screen of indicator of system of radio-vision (SRV) is submitted.

One staff of RI represents a spatial spectrum of road conditions in front of VC in coordinates range – an azimuth corner. On presented RI staff (Fig. 2) borders of road, a roadside and a vehicle (on distance of the order of 170 m), moving on a counter lane clearly differ also.

Additional task of secondary data processing is transformation of coordinates received RI from coordinates range-azimuth in coordinates range-range. The given mode is organized in existing experimental sample CRVS (Fig. 2(b)) in real time.

In Fig. 3 the principle of formation of radar file data in CRVS is shown. The working sector of scanning antenna

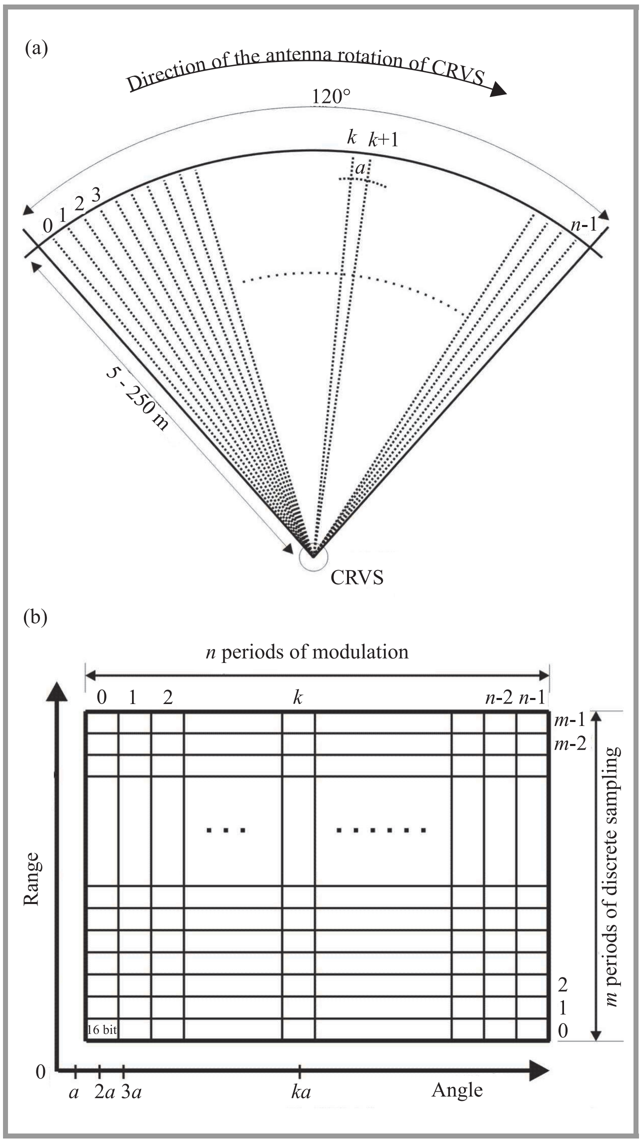

Fig. 3. The principle of formation of radar file data in CRVS: (a) working sector; (b) structure of the staff of radar image (array $m \times n$ 16-bit words).

of CRVS makes 120°. At an input of the antenna in working sector, on a signal from the gauge of the antenna position, ADC starts to digitize the mixed signal from the receiver output. Word length of ADC is equal 10, frequency of digitization: $f_d = 20$ MHz. In operating mode of CRVS with frequency of antenna rotation: $f_{ar} = 8$ Hz, with modulating frequency of LFM signal $F_M = 8$ kHz and decimation factor: $d = 4$, the RI staff of CRVS it is possible to present as a two-space file $(m \times n)$ 16-bit words in the size: size = 832500 byte.

The work of CRVS is organized in real time with frequency of reproduction of RI staff: not less than 8 Hz. Such work means high-speed data transmission with DSP on a HOST-computer for the further processing.

The size of a network used datagram protocol (UDP)-package is limited by requirements of the standard of transfer Ethernet or of standard USB 2.0 (Universal Serial Bus) which has high throughput and makes up to 480 Mbit/s. On the end of a cycle of the receiving, corresponding one pass of working sector, to accepted data radar file, FFT procedure is applied to formation of a spatial spectrum – staff of RI.

3. The Mobile Test Stand

For research of the statistical characteristics of RI received on CRVS output, at a stage of natural tests it is necessary to provide synchronous record of optical and radar images of road conditions. In the further, at a stage of the laboratory analysis of the real experiment, the received record enables the comparing of these images and in more details to check up conformity of RI to real conditions.

In Fig. 4 the block diagram of mobile test stand of CRVS is shown. Basic module of CRVS – radar is installed on a roof of a car. In the same place, with the purpose of fixing of the optical image, the portable video camera is installed also.

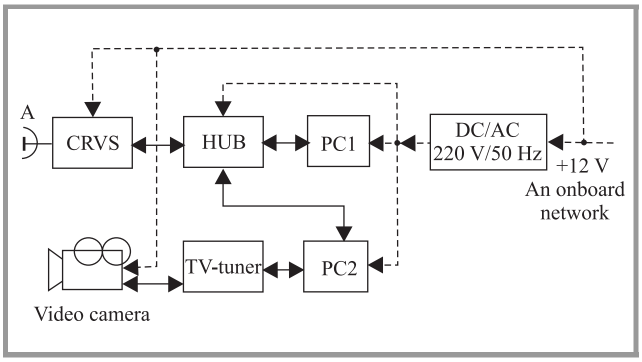

Fig. 4. The block diagram of mobile test stand of CRVS.

At the organization of an operating mode with a synchronous conclusion to indicator RI and OI (optical images), and simultaneous fixing of these data on a hard disk also, has arisen a problem of shortage of speed of the PC applied as an operating HOST-computer. To maintenance of synchronous record OI it has been decided to apply the second personal computer (PC2 in Fig. 4).

4. Main Design Activities for Synchronous Fusion of RI and OI

For synchronous record optical and radar images on a hard disk both of computer PC1 and PC2, and radar also, are incorporated by means of network HUB in a local network. By inquiry of the operating program with PC1, radar begins data gathering in working sector. Simultaneously with inquiry to radar on reception of data from radar, PC1 sends on PC2 a command on fixing of the optical image from a video camera. Received from RI it is fixed on hard disk PC1 and then it is deduced on the indicator – screen PC1. Thus the staff of the optical image from a video camera, it is fixed in a corresponding file of experiment on PC2.

Requirements to synchronous fusion of radar and optical images:

– time synchronization during formation of images on the interface of a stand;

– coordination of the aperture and quantity of information pixels of images at an azimuth;

– coordination of information velocity: the optical image – 24 Hz, radar-tracking: 10–15 Hz.

In Fig. 5 the staff of optical and radar images who has been written down synchronously during natural tests of CRVS are presented.

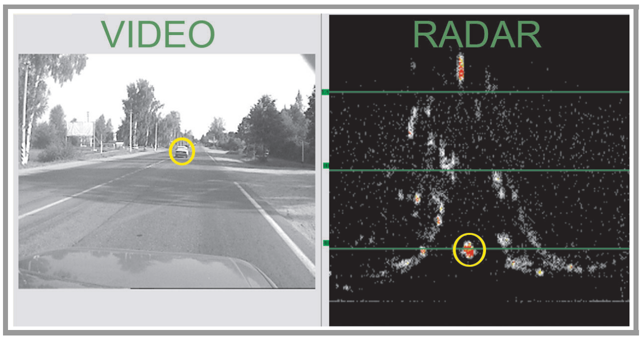

Fig. 5. Synchronous record optical and radar images.

Taking into account increase of requirements of traffic safety of vehicles in conditions of absence or the limited optical visibility establish the increasing quantity of various information sensors: optical, radar, infra-red. In result there is an opportunity to realize of fusion sensors. This problem is known for a long time and successfully is solved at construction of navigation systems of modern planes and helicopters. The essence of a problem of fusion consists in use of the several sensors measuring identical parameters or forming identical images, in aggregate, to receive more exact measurement of parameter or the best image.

The basis of an advantage at fusion consists that each sensor has the advantages and lacks. Therefore, using ad-

vantages of each sensor, at fusion will be received "more exact" results or the better informative image on an output of a complex.
With reference to our task on the automobile is possible fusing of the following sensors:

– homogeneous (same) sensors, for example, radar-tracking sensors of long and small range;

– heterogeneous (diverse works by a physical principle) sensors, for example, the radar-tracking sensor of long distance and the infra-red or optical gauge.

It is represented to the most effective fusing of panoramic radar of forward review (CRVS) and a video camera.

5. Conclusion

The considered features of formation and processing of RI in CRVS have allowed to formulate requirements concerning the size of the image, system of coordinates, speed of transfer of figures and creation of processing in real time, system of display of RI and synchronization.
On the basis of analysis RI, received as a result of natural tests CRVS, tasks of secondary processing RI for formation of the radar image adequate for the driver of the received image has been determined. For creation of algorithms of secondary processing RI on the basis of test stand CRVS requirements to the module of time synchronization has been determined at display, record and overlapping RI and OI.

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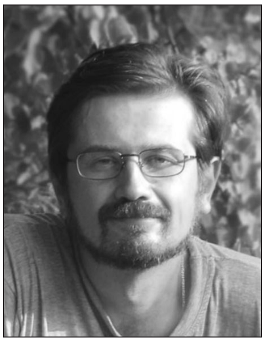

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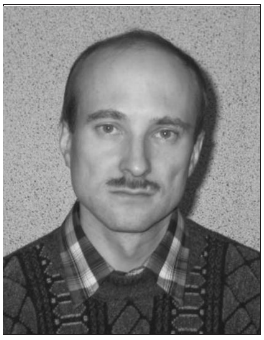

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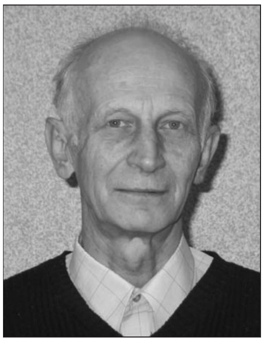

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