An Above-water Testing's Result of Experimental Surveillance Radar with 64–Channels Digital Antenna Array

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***Abstract*—In this article are analyzed a results of experimental radar with digital antenna array full-scale test against above-water targets, small-boat detection and tracking. (Abstract)**

Keywords-digital antenna array (DAA), analog-to-digital convertor (ADC), radar, transmitter (key words)

I. Introduction

The most urgent and determinative characteristic of new generation radar is the usage of DAA technology for antenna system fabrication. The current base capabilities allow of getting the most compact engineering solutions, for example the experimental radar with 64-channel DAA constructed by ARSENAL Corporation, Kyiv. Its construction is conditioned by the necessity of principal regulations practical check in the theory of multichannel signal analysis and effectiveness of existing DAA in the frequency range approximately 10 GHz. Successful full-scale test of this radar was conducted on the research laboratory of ships physical fields testing area of Mykolayiv shipbuilding center based in Sevastopol in October 2009 - 2010.

II. Main Text

Before starting direct description of tests we should mention technical characteristics of experimental radar. Its distinctive feature is the distributed execution of reception and transmission segments with coherent signal processing. Radar consists of: reception system (pic.1); transmission system, constituents of horn antenna and solid-state amplifier; display device on computer basis. The reception system is the passive DAA formed by a range of subsystems including (Fig. 1):

- antenna array comprises 16 lines containing 4 vertical elements of print type each;
- 64-channel reception microwave module with 128 quadrature signal output of intermediate frequency;
- oscillator module and control signal forming;
- 128-channel intermediate-frequency amplifier module;
- block of 128 digital reception modules with calculator and synchronizer.

Patented technical solutions described in clause [1 - 5] have been used during radar creation. Recommendations [6] concerning industry standard CompactPCI usage were proposed as the conceptual principles of constructive digital reception modules block creation. ADC capacity – 12 bit, sampling frequency– 50 MHz. Transmitter radiation pulse power is approximately 40 Watt. Signal polarization is vertical. The duration and recurrence period of monitoring impulses adjust programmatically. The shortest radiative signal is 0,64 microsecond (µs), the longest - 5,12 µs. The maximum dimension of pulse packet accumulation is 256.

The transmission device (Fig. 2) was located at a distance from 1 to 6,5 m remote from antenna array during the tests. Since no evident influence of transmitting device influence on radar operational capacity was detected, while the creation of radar with DAA of different assignment joint as well as spaced structural arrangement of reception and transmission devices can be recommended.

On the first stage of tests most of attention is concerned to the technical state stability of reception paths investigation. As stated in [7], the adjustment reception system is one of the most important procedures, typical to multichannel systems created using DAA technology. During experimental tests the adjustment of DAA is provided in several stages. The main is the assessment of receive chain condition, i.e. calculation of correction constant that combine relative divergences (amplitude and phase) of channel transfer constant, that are measured according to external control signal. The information about divergences of all reception paths elements is concerned in these constants.

In the view of the fact that this stage demands special signal provision, it is impossible to conduct it frequently in terms of radar basic mode. Thus the second variant was conducted – the correction in terms of internal control signal [7]. Received correction constants contain only divergences in constants of receivers transmission, control signal separation network and connection keys of control signal to receiver entry (parameters of these elements are considered as invariable in time).

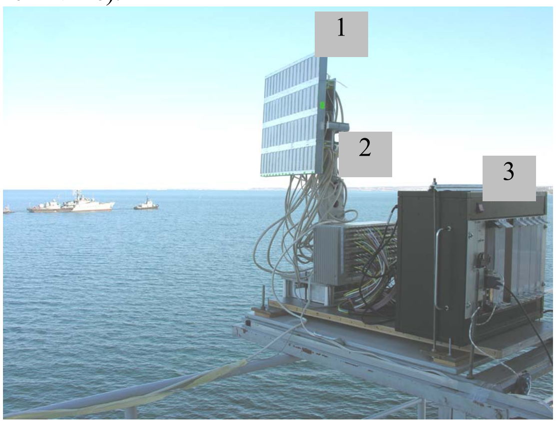

Figure 1. Radar reception segment («1» - 64-channel reception microwave module; «2» - 128-channel intermediate-frequency amplifier module; «3» - block of 128 digital reception modules with processor and synchronizer).

Figure 2. Radar transmission segment.

Differential correction constants of first and second variants according to proposed method [7] of DAA adjustment allow calculate final correction constants that according to suppositions about statistic characteristics of reception paths elements parameters provide possibility of effective DAA channels correction. For the calculation of them it is enough to provide correction constants calculations periodically by means of internal signal source only.

During test environment in the capacity of external control signal the following was used:

- transmitter coherent signal from angular reflector;
- incoherent signal of autonomous wide band oscillator radiated by transmission horn;
- coherent microwave signal of transmitter startup from synchronizer of radar reception system to horn antenna connected by means of 10-meter cable 20 dB damping.

According to first two signals we failed to perform qualitative adjustment of DAA channels because of multiple re-reflections influence from surrounding subjects. As appeared, incoherent signals field reflected from underlying grass surface was too unstable and did not allow us to take into account multiradiate radio wave spreading.

We succeeded in performing DAA adjustment relatively precise by means of horn antenna usage that is connected to microwave signal output of radar transmitter. Adjustment signal was in continuous operation. The distance between antenna array and transmitter horn reached 8,8 m; the height of reception antenna array aperture centre coincided with the height of phase center of external control signal horn antenna transmitter. Adjustment constant was defined (compare) taking into account front edge sphericity of wave on the aperture of reception antenna according to method [7] as well as without factor of sphericity.

The quality of channel characteristics equation (adjustment) similarly to [8] was estimated according to divergences of phase and amplitude vectors of signal voltage regarding channel taken as standard one. Apart from this the output voltage of all reception channels were displayed on the operator's screen by means of vector diagrams [8] where vectors amplitudes and their attitude position were conditioned by received signals complex amplitude parameters.

The received results during the first stage of tests gave us the reasons to conclude about the effectiveness of proposed method [7] of equalization of parameters of DAA physical channels.

On the second stage of tests most of attention was paid to radar operational capacity and operational quality check in the real radiolocation environment. Radiolocation targets were the above-water objects that were located in the radar operating zone during the tests.

Laser rangefinder DAK-2 was chosen as an instrument of objective control, by its means the distance and direction was calculated.

The weather conditions during the tests: atmospheric temperature 18…23 degrees, variable cloud, moderate breeze up to 5…7 m/s, sea state from 1 to 2…3 points.

Radio engineering environment was getting more complicated by the reasons of twenty-four-hour operation in circular scan regime of "Nayada-5" radar from the pilot post in the distance of approximately 100 m. The operating frequency of "Nayada-5" almost coincided with the frequency of experimental radar transmitter that resulted into asynchronous interference on the inputs of reception channels especially during the operation under short monitoring pulses.

The operation of radar under test was conducted in sectors: 18 degrees angle of elevation and ± 30 degrees by azimuth – in signal reception regime; ±15 degrees angle of elevation and ± 10 degrees by azimuth – in monitoring regime. Even so transmitter radiated the whole sector and the reception of reflected signals occurred simultaneously from all directions in terms of reception antenna array operating sector. The coordination of operating sectors location of reception system and transmitter was manually conducted by means of optical viewing device.

Radar results were displayed on monitor sector scanning "distance – angle of elevation" and "distance - azimuth" of operator in the view of:

primary signal that exceeded fixed detection threshold;

detected targets record;

record of targets, covered by trajectory tracking.

Apart from this track target table of forms was displayed on monitor by the following parameters: target number, target coordinates (azimuth, distance, height), relative bearing (azimuth), target headway and vertical speed; number of received radar targets, the magnitude of relation "signal - noise" in the last count in decibel.

Radar operating conditions, radiated impulse signals parameters, number of probing cycles, monitored noise level of reception devices, the magnitude of chosen detection threshold and the number of detected signals were registered on the control panel. While transition into service operation mode the existing software allowed to display on operator's monitor timing and spectral data of received signals, the magnitude of monitored parameters (distance, azimuth, angle of elevation, radial velocity) of detected signal sources and other data.

During conducted experiments by means of radar with DAA almost all above-water objects in the defined operational sector (notably marine buoys, movable and unmovable boats, motor and sail yachts, cutters, boats and ships of medium and large tonnage) were detected and continuously traced.

In the definite distance mode the following typical above-water objects sequentially accompanied:

- military Ship «Kerch» - from the distance 14,43 km to the distance 34,5 km; radiated signal parameters: impulse duration – 5,12 μs, number of impulses in a pack – 256, i.e. total time of signal coherent integration for single mark obtaining is 208,4 ms.
- submarine in above-water position - on the distance 8,9 km;
- moving small yacht at the distance 9,76 km.

During the comparison of distance measurement results of radar with the data from laser rangefinder DAK-2 the difference was 3…10 m for unmovable objects, up to 30 m for movable objects. On the ground of visual control and objects coordinate measurements results by means of laser rangefinder the identification of detected targets was provided. In general, the comparison of measurement results of targets range and azimuth with the data of laser rangefinder pointed their differences in terns of potential accuracy of DAK-2 device.

During the tests extended functional capabilities of radar with DAA were checked. Notably:

steady operation with failure in one or more reception channels, including breakdowns of three from four horizontal lines of antenna array elements;

local as well as detected and tracked objects binding to the field (map)

determination and display of radar own coordinates;

accountability of antenna slew while display of situation on the map;

operation with different duration and monitoring pulse ratio;

target tracking in quasi-continuous radiation mode;

operational capacity of device in the environment of nonsynchronous impulse interference influence created by radar "Nayada-5";

radar operational capacity in the environment of intensive rain and wind (steady detection of above-water objects at the distance up to 8 km and tracking of targets kind of boat and launch (longboat)).

Conducted full-scale tests of experimental pattern 64-channel radar created by the technology of DAA proved the effectiveness of main construction principles [6], implemented technical solutions [1 - 5] and developed software and algorithmic provision. Notably the following was confirmed:

realization ability of spatial (and frequency) principle of parallelism (multichannel) of DAA reception system on the modern base in the real time;

algorithm effectiveness of digital equalization of reception channels transfer constants, that actually secures difference of transfer constants about few units of percent by the amplitude and parts of degree – by the phase;

high coherence of radar is achieved by means of forming of all radio- and control signals from the vibration of a single stable quartz frequency generator 100 MHz;

multichannel algorithms of signal detection and their quantity evaluation (by comparison of angular coordinate and speed) operation capability;

practical realization ability of algorithms of multi-impulse measurement of angular coordinates and targets velocity characterized by super-Rayleigh resolution;

effectiveness of developed algorithms of targets trajectory tracking;

correctness of developed algorithms of common display on the indicator screen of received radar data and the field;

comfort and informativity of information display form on indicator screen in different modes realized in radar;

high effectiveness operational capacity of retention algorithm of radar with DAA reception system during failures of few physical reception channels;

functionality of developed software and algorithmic provision of radar that allows to perform the whole cycle of radar battle service in automatic mode;

the effectiveness of chosen estimation procedure of radar capabilities performed by means of DAA technology.

III. Conclusion

The experience obtained during development of experimental radar and results derived during tests enables successful creation of radar with DAA experimental pattern that would satisfy the demands of severe severity conditions in the abovementioned and bigger formats of antenna array.

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