AERO INDIA 2007

Zhuk–AE airborne radar

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Deputy PM sends a positive message to MiG

Sergei Sokut – chief officer, RAC MiG Public Relations Department Information Center

Sergei Ivanov was the first top-level government member to be shown the cutting-edge MiG-35 fighter.

Deputy Prime Minister Sergei Ivanov's trip to RAC MiG's production site in Lukhovitsy on January 9 was the first important event in the Russian aerospace industry this year.

This visit cold qualify as a special milestone on many counts. For the first time, a top-level government official came to an aerospace production site less in his political (deputy PM and defense minister) than professional capacity. On December 12, 2006, Ivanov was appointed board chairman of the newly created United Aircraft Corporation, a government-owned entity run by MiG's CEO and designer general Alexei Fedorov.

Ivanov did not waste time to make clear that he has a consistent vision for the role of the new holding company: "We will be able to bring our corporation back to the top league of the global aviation industry."

To achieve that goal, he also formulated UAC's closest objectives: To define the product lineup that would be competitive and aligned with national defense interests; to make full and efficient use of modern financial mechanisms for successful corporate buildup and development." His MiG visit was an important step toward both targets because MiG, though not yet part of the UAC, will join in later this year, which Ivanov himself corroborated, praising the company for "very good performance in recent years."

The Lukhovitsy site is MiG's key production asset. In the future, it will produce both military and civilian aircraft, the latter together with international partners. It perfectly matches the objectives set out by the UAC Board Chairman, which probably explained his keen personal interest.

During the visit, Ivanov again reasserted both key targets, urging the company to make use of the expertise amassed in defense and transport aviation to successfully introduce the commercial production of civilian aircraft."

Ivanov expressed confidence that the MiG facility could successfully accommodate both lines of business, an attitude that is well explained by what he saw there. Some of the technologies and equipment used in Lukhovitsy are arguably the best in the industry. One example is the wide use of most advanced composites for MiG aircraft. The excellent product lineup is the best proof of MiG's technological leadership and dependability of its suppliers and contractors. Ivanov was briefed into the features and performance of the corporation's key products in the assembly workshop, the most modern facility of the kind across the nation.

The MiG-35, for the first time on public display, was best oroof to Sergei Ivanov's previous remark: "our defense aircraff industry is still in the global top league." Reporters were deprived of detailed information about the new fighter but what they saw was clearly enough to assess its technological advantages. This is the first Russian aircraft to carry a Generation 5 active phased array radar, the Zhuk-AE made by Phazotron, MiG's key partner.

Zhuk-AE radar on the MiG-35 fighter

By making such an advanced radar, Phazotron, represented in Lukhovitsy by deputy CEO Yury Guskov, proved to the deputy PM that Russia could sustain its leading positions in all sectors of the industry independently, without outside support.

The new MiG's radar is not everything the aircraft touts. The optics and electronics are a dramatic advance compared to the previous MiG-29 Fulcrum derivatives (MiG-29K and MiG-29M2). Sergei Ivanov was especially interested to hear that the MiG-35 optics and electronics suite for the first time included systems developed by the Precision Instrumentation Institute, usually focused on space.

New equipment was not presented in detail; some of it was even veiled. However, an expert's eye could tell that it would mark a great improvement in self-defense and especially in air-to-surface combat capability.

The first MiG-35 is equipped only with Russian systems but another key point about this aircraft is that it can be adapted to foreign equipment as well, which will bolster its prospects on international markets. Its fist test is due to come soon: the Indian Air Force is holding a major tender for its MMRCA program. Sergei Ivanov, in line with the recently adopted strategy, promised comprehensive government support.

"As India is going to announce a tender for a large light fighter fleet, Russia will present MiG's bid very vigorously," he said.

In late January, Ivanov will co-chair the Indo-Russian Commission on Military-Technical Cooperation – a major opportunity to visit India and discuss the MiG-35 issue with the Indian partners.

In the civilian department, MiG is going to confront more difficult challenges. The UAC Board Chairman sees two ways to address them: importing technology and expertise from the military domain and developing international ties. Ivanov said EADS had agreed to consider Lukhovitsy as a production base for cargo Airbuses.

The business session that came after the MiG-35 presentation was closed to the media. MiG Corp. came with a short statement, saying the agenda included a range of issues on MiG and UAC's future in the aerospace business.

The constructive atmosphere of the visit and Sergei Ivanov's clear interest in the issues confronting the Russian aerospace area have sent a strong positive message to the industry and beyond that the sector deputy prime minister is now responsible for is looking at a bright future.

Sergei Ivanov is being looking into the design of the Zhuk-ME radar for the MiG-29SMT fighter

Common Work Toward Common Goals

Viktor Komardin – deputy Director General, Rosoboronexport

These days mark the 44th anniversary of the first six MiG-21F13 (Fishbed) tactical fighters arriving in Bombay (Mumbai) to form Squadron 28, the first Fishbed-equipped Indian Air Force unit. Several years later, the HAL factory in Nasik began the production of the MiG-21FL derivative especially for India.

The past four decades have radically changed the political map, and fighting forces have moved on with the times. What is important about the relationship between our two countries, however, is that we, in this pragmatic world of ours, have always relied on strategic partnership and mutual trust that have underlain our military-technical cooperation.

In retrospect, we ought to be proud of the Russian scientific, designing, and engineering role in the development of the Indian armed forces and its defence industry. This long-standing cooperation has helped to make the Indian fighting force one of the strongest around the globe, with a flexible, responsive, comprehensive, and highly efficient air capability.

As a major vehicle of Russia's military-technical policy, FGUP Rosoboronexport has always placed a special emphasis on cooperation with its Indian partners. In recent years, India – largely its Air Force – has accounted for more than 30% of demand for our hardware and services.

This explains our willingness to be part of Aero India 2007. Naturally, we see this air show as yet another chance to demonstrate the advantages of Russian aircraft, but for us it is also a tribute to a great tradition and an important sign of continuity of the work we have been doing together for decades – and of the dialog with our friends in India on a wide range of current and future projects. We have highlighted the joint development and production of medium-haul fixed- and rotary-wing utility aircraft – projects that are expected to determine new approaches to future aerospace cooperation.

Working as an equal partner in designing and producing near-term aircraft, India not only gets the prospect of acquiring a unique air-fighting capability, but also secures access to cutting-edge aerospace technology.

On the fixed-wing utility aircraft project, all the performances and technical outlines have been agreed upon, and a new fully prioritised business plan is already in place. The Russian Air Force is expected to order 100 such aircraft, the Indian Air Force will buy 45. As soon as an intergovernmental agreement is signed, this project will leap ahead.

Rosoboronexport has accepted HAL invitation to bid for the joint development and production of 10-ton utility aircraft for the Indian defence and other government institutions. Together with Mil Helicopters, the leading Moscow producer, we have come up with a bid that includes the transfer of the latest know-how other bidders are highly unlikely to share. We are aware that our bid is competitive and attractive and believe that the tender committee will appreciate it. In a separate tender, Rosoboronexport and Kazan Helicopters are competing for the supplies of the Mi-17V5 (Hip) utility helicopters for the Indian Air Force.

Il-76MKI and Su-30MKI (IAF) in an air refueling exercise

Currently all Indian medium-haul military helicopters are of Russian design (Mi-8 and Mi-17). They have demonstrated superb performance in Kargil in 1999 and in the alpine environment of Siachen Glacier. The Hips have won high praise for successful operation in adverse conditions, such as powerful descending and ascending air turbulence, extremely low temperatures, and strong winds (up to 90 mph), which makes us confident of their impeccable reputation in this country and of the bright prospects of our future cooperation in this field.

As the Indian Air Force operates several squadrons of the Su-30MKI Flanker, HAL has already declared readiness to produce more. Additional supplies from Russia are also being considered.

This Flanker already provides unmatched air-to-air and air-to-surface firepower, but there is always some room for improvement if you know where to look. Russia and India have been very successfully looking into the BrahMos, a new air-launched missile that will be compatible with the Flankers.

Technological and other consultations are successfully moving ahead on the joint development and production of Kaveri, a new jet engine for the near-term Light Combat Aircraft. Our action plan based on the NPO Saturn technology suggests that Russian know-how will merge with India's scientific and production achievements to make HAL's Kaveri project as fast and cost-efficient as possible.

MiG-29M2 performs a Pugachev Cobra

India and Russia already have a long record of success with aircraft engines. One great example is the recent engine replacement agreement for the MiG-27 (Flogger), Il-76 (Candid), and Il-78 (Midas) aircraft. HAL's Karaput unit is expected to produce new RD-33 Series 3 engines for the MiG-29s (Fulcrum), starting with a batch of 120 ready engines and setting up a repairs service.

The production of deck-based MiG-29K/KUB fighters for the Vikramaditya, the new Indian aircraft carrier, is another very important and very successful project. Major Russian radar producer Phazotron is equipping them with its cutting-edge Zhuk-ME systems, equally effective against surface as well as aerial targets.

RAC MiG will also present its new 3D thrust-vectoring MiG-35 multirole fighter with a full low-speed-high-AOA capability, critical to success in air combat.

I also feel obliged to mention the recent tensions on the MRCA program, including apparent misperceptions of Russia's position as an attempt to exert pressure on its Indian partners and squeeze favourable concessions on direct offsets and other rules of supplies. India is a large importer of military hardware and understandably needs to use its purchasing power to develop national industrial capabilities and – which is the underlying principle of direct offsets – ensure reliable supplies of spare parts, services, and upgrades for the operational fleet.

Su-30MKI (IAF)

On our part, we intend to dramatically improve the quality of post-sales services by establishing joint service centres locally, not only with government-owned, but also private government-approved Indian companies.

Another great window of opportunity is seen in piloting and service training, where Russia offers off-the-shelf training facilities and simulators. We are sure that our offers on simulation systems for the Il-76, Il-78, Su-30MKI and Mi-8/17, made fully in line with the IAF requirements, will be attractive enough to be approved by our partners. Russian ZAO R.E.T. Kronshtadt offers a comprehensive helicopter training facility with simulators and computer labs, where various liaison IAF-Army, IAF-Navy, and IAF-IAF solutions can be simulated. We are positive that the joint-arms nature of modern and future warfare requires equally multifunctional and multi-layer simulation facilities integrated with automated C4I systems.

The list of activities mentioned in this article represents just the tip of a powerful iceberg that Indo-Russian military-technical cooperation is. It does face many challenges that ought to be addressed on a joint basis, but what is important is that there is mutual understanding of our common overarching goals and ways to achieve them. This gives us confidence of the future growth and robustness of strategic partnership between our nations.

Project 636 Kilo Class submarine

Phased-array radar: first time in Russia, first time on Fulcrum

Mikhail Korzhuev – Director General, Phazotron NIIR Corporation

MiG is a well-known brand and a sign of quality and innovation for the global aerospace community. Every time MiG comes up with a new aircraft, it means a leap ahead in aerodynamics, power plant, and avionics for the global industry – while the MiGs become ever simpler to operate and maintain. This is an integrated research-and-production corporation which dates back to the Soviet Mikoyan Design Bureau and with all its long history has demonstrated remarkable flexibility and business talent in a free market environment. With a unique offer on the current marketplace, the sky seems to be the limit.

The latest upgrade of the classical MiG-29 Fulcrum, the MiG-29M OVT, stunned Farnborough audiences last summer with exquisite thrust-vectoring aerobatics. The next step to a full combat air domination is advanced avionics, including a phased-array radar.

The future MiG-29 derivative prepared for the Aero India 2007 will be equipped with the Phazotron Zhuk-AE radar, the first Russian phased-array system developed for the Fulcrum family.

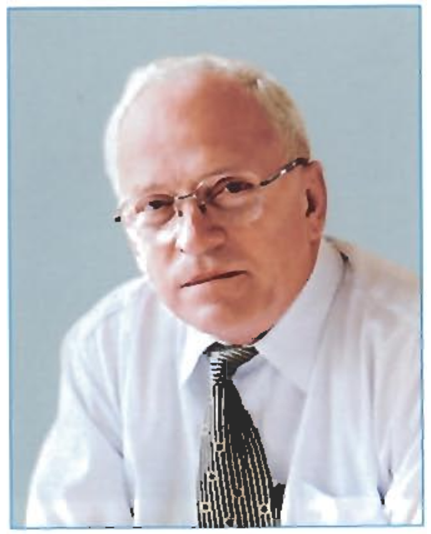
From the very start, the project was a risky venture. We had to persuade people that those who dismissed Phazotron (as well as MiG itself) as obsolete and hopelessly lagging behind the industry were very much erring on the pessimistic side. Part of the credit for the fact that we did it and then delivered on all our promises lies with MiG's new management who came just in time to merge their exceptional technological, economic, financial and managerial skills with bold vision and thoughtful insight.

Radiating new confidence, they also helped us to build a new strong, innovative, and highly motivated Phazotron – a company that knows about radars.

The Phazotron vision of phased-array radar technology was published in the previous issue of this magazine. This issue goes a step further, telling our readers where we are today.

Active-Phased-Array Radar: History and Progress Made

Yury Guskov – deputy Director General and deputy Designer General, Phazotron NIIR Corporation



Technology

For decades, Phazotron has led the industry in the development and production of onboard radars. Although it is not involved in Russia's broad 5G fighter effort, we have been working hard on an airborne active-phased-array radar and at this point are outperforming the team working on it officially, for several reasons.

First, all our products have been designed in a classical comprehensive way: basic research, R&D, experimental production, commercial production – the only reasonable way to make a working commercial product.

Second, Phazotron clearly runs the best airborne radar research school in this country.

Third, Phazotron's active-phased-array radar effort has been focused on the MiG fighters – first as an independent venture program and since recently as a joint Phazotron-MiG investment.

Below is a concise list of preliminary projects we made as part of the active-phased-array radar design:

- making sure that active-phased-array radars will really work better for fighter jets than traditional radars;
- finding an optimal layout;
- finding partners and subcontractors with relevant experience and capabilities;
- splitting the design into self-sustained modules to launch a massive research offensive in all these areas simultaneously;
- designing new production technologies to make mass production as cost-efficient as possible;
- making and testing experimental products.

Infrastructure

Technological progress is a spiral, rather than a ladder: you cannot go from one step to another all in one leap, leaving the entire world behind, without creating the necessary infrastructure which comes only through very fine steps with costly basic research involved. In our case, that meant new microchips.

This step, however, is possible only after the need for active phased arrays has been undeniably established. It was, and here is a list of APA's most obvious advantages:

- it controls the beam electronically;
- its transmitter and receiver are very close to the radiating element, which means low power losses;
- it operates in a broad waveband which makes it compatible with various radiating elements, including those of electronic countermeasures and even wireless data transfer systems;
- and, most importantly, it is more reliable than traditional systems.

An active phased array includes a radiating element, a transmitter, and a receiver. Transmitter is any radar's most fragile element: if 10% of about a thousand transceivers in a typical active-phased-array radar fail, the whole system fails, while theoretically, the active phased array radar has a service life of 10,000 hours, comparable to that of the aircraft itself. This means that reliability in every point is crucial.

Active-phased-array radars create a new quality of air combat, which justifies large investment.

Viktor Gyunter, Mikran Director General, presents the transceiver to Russian aircraft industry officials

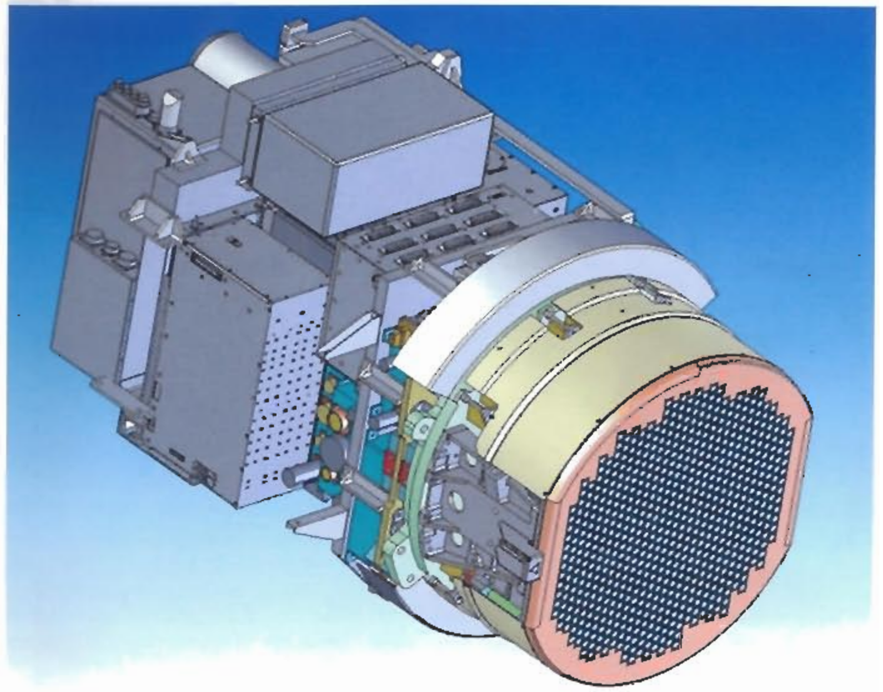
Partners

We in Phazotron analyzed our own capabilities and the existing market in the area and decided to outsource only the transceiver production. Of over a dozen Russian (only Russian producers were compared because of the sensitivity of the task) developers and producers we selected the Semiconductor Instrumentation Institute and NPF Mikran, Tomsk, considering that Mikran, relying on its impeccable credibility record in microchip production and convergence and on the scientific talent base of the Tomsk State Control Electronics University, would develop transceivers according to Phazotron's specifications, and the SII would use its production base to produce as many microchips as Phazotron might need.

Transceiver power amplifier setting system

Layout

We decided first to make an active-phased-array radar out of a traditional radar (it is the best option for the first step because the array is the only thing that is actually new) and only then proceed to new technologies and new elements because, although they promise higher performance, the risks involved are too high, and the entire program becomes too costly and time-consuming.



Initial-stage active-phased-array radar

Experimental production

Our first active-phased-array radar was in fact a derivative of the previous traditional radar, with the computing system (signal and data processing units), synchronized master oscillator, and the receiver (save the low noise amplifier and the ADC) taken from the previous designs (see the figure).

The second step will involve major improvements in the computing system and a broadband multi-functional master oscillator.

An active phased array program is bound to be expensive because many things have to be new; all the subsystems of the radar and its environment need to be closely monitored, and their performance adequately interpreted, which requires a qualitatively new pre- and in-operation monitoring systems.

The array, the most sophisticated thing in the whole effort, includes the following subsystems:

- the radiating curtain consisting of array elements;
- transceivers, each connected to a radiating element;
- a cooling system;
- a power system;
- a separate control system for each transceiver;
- an HF power distributor to amplify and phase the single power flow;
- secondary power sources;
- a beam control unit.

The teams working on the project split the work into the following fields, starting the work simultaneously as part of a broad research offensive:

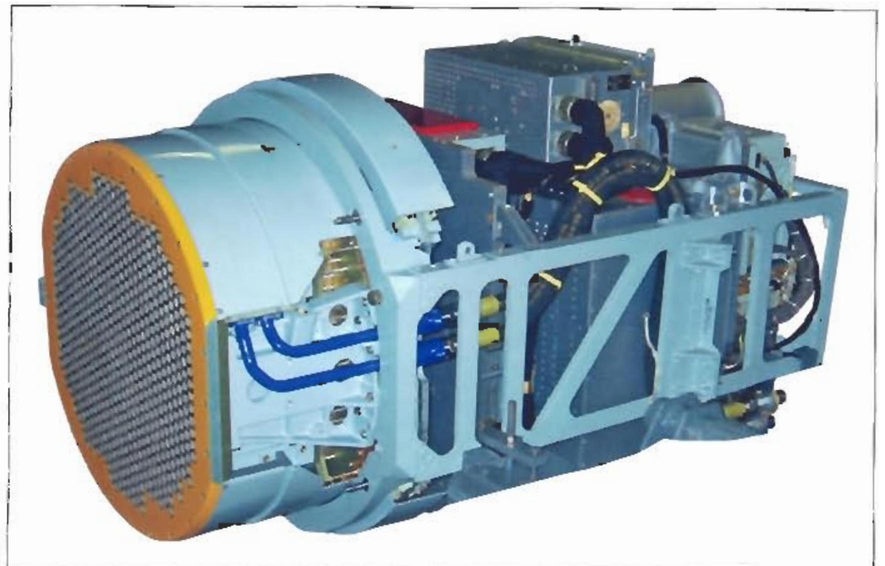
- aperture;
- aperture elements;
- transceiver circuit engineering;
- transceiver microchip design;
- transceiver modular layout;
- transceiver heat control;
- heat control efficiency and secondary power sources design;
- transceiver control design;
- transceiver secondary power system design;
- distribution of HF power coming from the master oscillator to the transceivers.

The transceiver, predictably, caused more problems than any other element. The array should work on 3-cm waves at the beam deflection angle of ±70° without any parasitic sidelobes, which is achieved at maximal deflection only if the distance between separate radiating elements is less than half the wavelength, while all the elements have to be small enough to make a compact, easily cooled, effectively controlled, and power-efficient radar. This is one of the most sensitive stages of the entire research effort, so it deserves more detailed consideration.

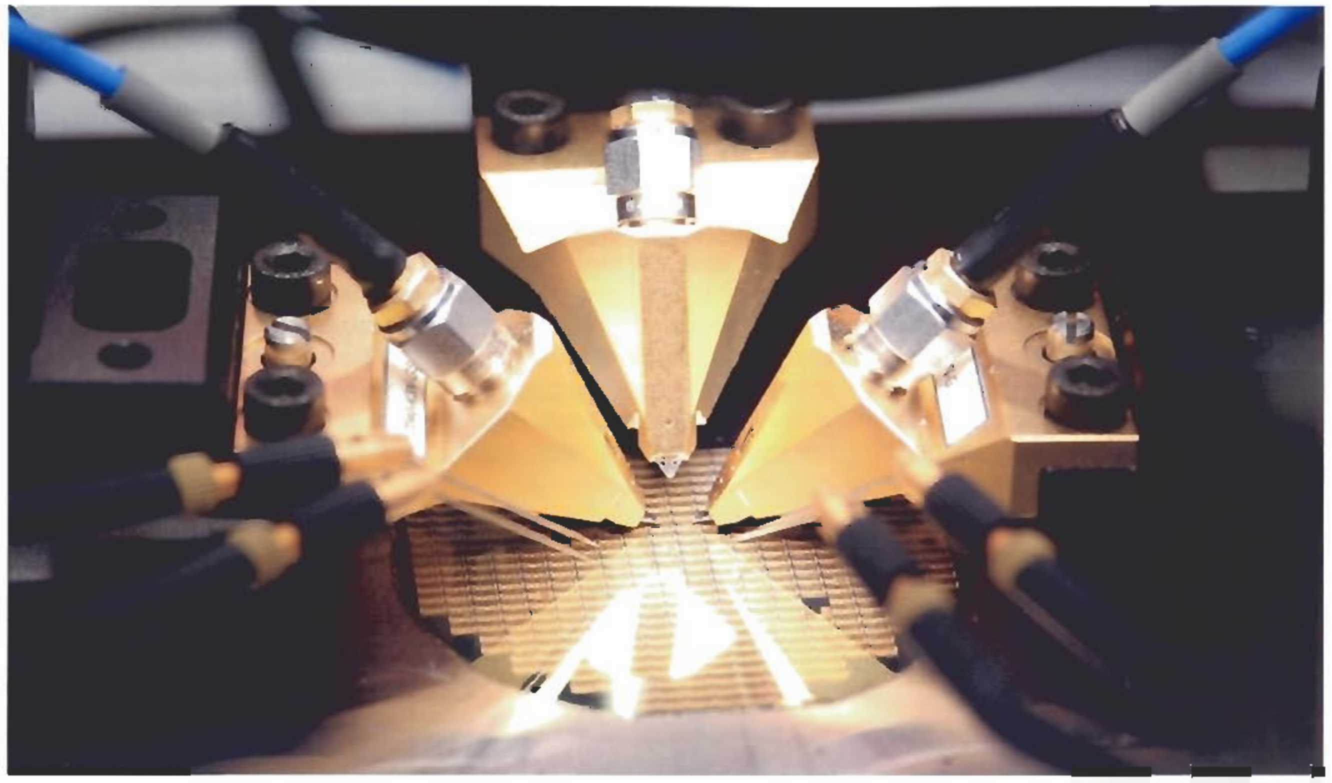
Transceivers must be as compact as possible. Height and width are important because there is little space behind the radiator, but designers around the globe also struggle with the length. This leaves integrated microchips as the only option for the element base. As the integration between the SHF and digital parts of the transceiver becomes possible, transceivers can become even more compact.

Another crucial parameter is the optimal power and efficiency of the output SHF transistor. We estimated it should be between 6 W and 8 W (linear amplification), given the amount of power aircraft can spend on the radar. Although transistors of this sort are made using the well-known GaAs technology, such high power would require some innovative cooling solution (double output power increases the radar's operational range by only 19% while requires a very sophisticated cooling system). Another issue is to use innovative materials, which have yet to be sufficiently investigated, in new microchips that also need to be as reliable (10,000 hours) as the array itself.

While the amplifier efficiency can be up to 50%, it is lower in the linear mode (usually 22% to 25%) because of the transistor. The saturation mode can raise it to 35% to 40% but results in nonlinearities and, accordingly, parasitic components in the radiated spectrum preventing efficient teamwork of several aircraft in one mission. So, if one is interested in a coherent and clear spectrum, anything but linear amplification is just out of the question.



First model of active-phased-array radar (Zhuk-ME)



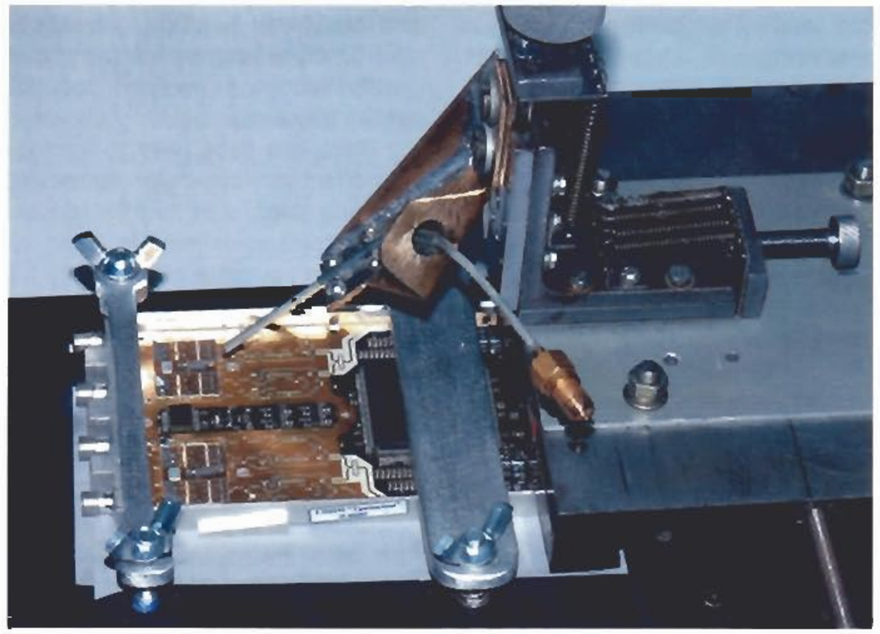
Microchip crystal presorting contact device

Configuration

The configuration was selected from dozens of various designs, with all their pluses and minuses.

For the transceiver, we selected the 4-channel version. One-channel transceivers were too poor-performing and hard to make, while multi-channel ones turned out to be better, and a system made of them could be genuinely modular. This left heat control the only major roadblock. The most sensitive element here was the output transistor. The effort resulted in an experimental setup providing high thermal conductivity and, accordingly, high efficiency.

With the experimental active-phased-array Zhuk-AE derivative, we made sure that traditional radars can be upgraded into active-phased-array radars with a new active array, new transmitter and receiver. This radar, the first Russian 3-cm active-phased-array radar conditionally adopted for the MiG-29 Fulcrum



HF-connection contact device (part of transceiver) tactical fighter, was the basis of all further studies.

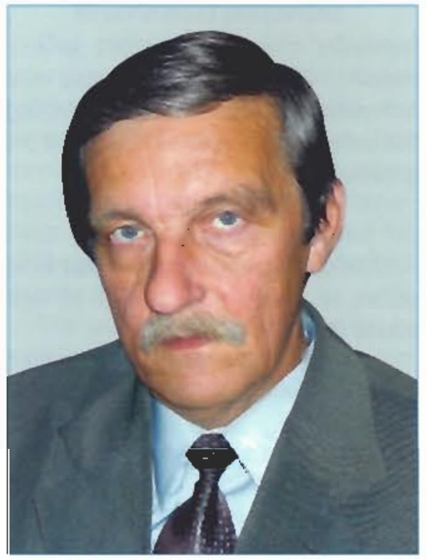
While the performance of the first Zhuk-AE proves that Phazotron has been moving in the right direction, it clearly has much room for improvement to make use of everything the active-phased-array technology can offer. We have thought of the following to-do list:

- fully automate the setting and testing of all APA elements to reduce research labor and time costs;
- produce unique specialized monitoring instrumentation for the APA to simulate real operational conditions (see Fig. 2 for the prototype of such an instrument for pulsed monitoring of the SHF and other array elements) and have it properly certified;
- design new production equipment (see Figs. 3, 4, 5 for prototypes);
- design a new test bench with the possibility to add new simulated operation modes;
- write more efficient firm- and software for the radar computer;
- devise more efficient layouts, signal processing methods and beam control strategies for the existing and future operation modes;
- develop a database to save and manage information on all stages of the radar lifecycle, provide statistical support and data mining to propose new research strategies.

While all this requires major investment, the potential benefit clearly outweighs the costs because we expect that the product will be less expensive. We also expect this investment to pay back after the sale of first 10 off-the-shelf radars. ●

Optimizing Active Phased Arrays

Alexander Dolgachev – head of section Phazotron NIIR Corporation



Decisions taken in the process of developing a radar are very often compromises between what the developer wants, especially from the system as a whole, and whether these re-quirements are realistic enough. Important points here are to estimate the costs involved and get rid of openly contradictive and poorly justified requirements. This article highlights some contradictions a developer of an electronically controlled beam radar (for example, active-phased-array radar) has to face and how to find a reasonable compromise between 'a system that fascinates and a system that fulfils realistic functions – in other words, 'a system that works.'

Bandwidth

An active phased array, works better is the band is broader. If this requirement is crucial to some core-functional im-provement (higher resolution, better signal processing etc), the investment is justified. But many are tempted to increase the bandwidth to use the array additionally for non-core purposes such as electronic countermeasures, surveillance, communications etc. These people somehow tend to forget that the radar would have to divide operational time between the detecting and ranging system and others. An active phased array simply cannot be used in two modes simultaneously, and whether the benefits are that critical to compromise the pilot's ability to see the battlefield while his communications system is working is highly questionable.

Transceiver radiating power

On the one hand, it is understood why people want to increase the output power: to increase range. However, doubling the power gives you just about a 20% increase while this means that the radar takes double power from the aircraft and emits two times as much heat. The power-vs.-range curve in Fig. 1 was calculated for a powerful 5-W baseline transceiver with hypothetical amplification from 1 W to 15 W. The graph in Fig. 2 shows how the range changes as power consumption goes up. The range gain drops as the transceiver eats up more and more power. The conclusion is that the transceiver power per channel, as well as the number of active transceivers and the array aperture, should be determined by whether the aircraft can supply enough power and cool the system effectively.

There is a better way to increase the effective range: by increasing receiving gain. To do this, the receiver in the transceiver module must be active and the noise generated by the amplifier should be mitigated. Figure 3 shows the range-vs.-amplifier noise curve (the gain rises as the noise drops) which demonstrates that dampening the noise 10 times gives you plus 80% to the baseline effective range, without any extra power consumed or any extra heat emitted. This also means that other aircraft systems need not be modified to accommodate these extra power and cooling costs.

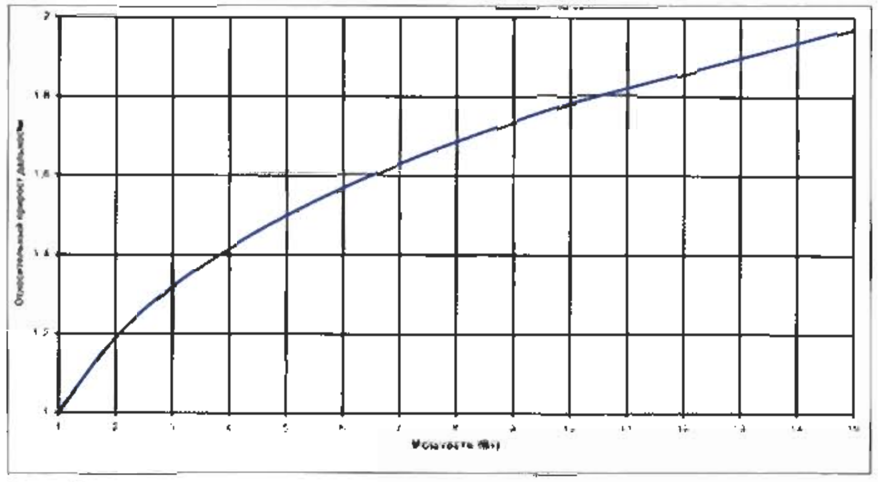


Fig.1. Range (relative) vs. power

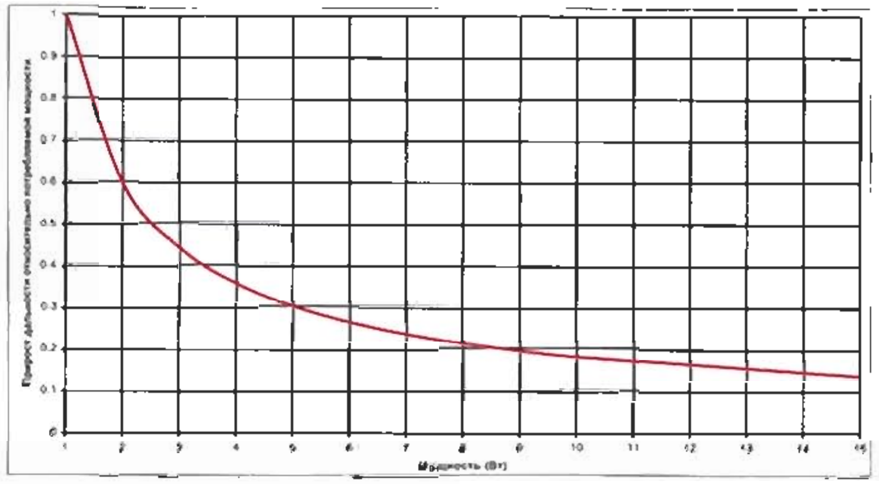


Fig. 2. Range gain vs. power gain

Electronic scanning sector

Any electronic scanning device is less effective when the beam deflection angle is large. This is a natural phenomenon explained by the beam broadening. The aperture efficiency drop is proportional to the cosine of the angle between the perpendicular to the array surface and the actual beam di-rection. Directionality is necessarily going down as the beam broadens, even if you use isotropic radiating elements. The curve in Fig. 4 shows this dependence for an active phased array with ideal isotropic radiating elements. Apart from the loss of directionality, the direction-finding curve steepness is also going down and is distorted because the maxima of the difference pattern are different (see. Fig. 5): as long as the beam deflection angle is no more than 60 degrees, this curve is almost linear (which means it will be corrected by the software without compromising performance) but as soon as it goes over 60, the curve becomes clearly nonlinear and very hard to correct. As a result, at large deflection angles angular errors are bound to increase.

The electronic scanning sector can also be broadened if the active phased array is curved but that requires a larger aperture, which is not always possible in a space-critical environment of the aircraft.

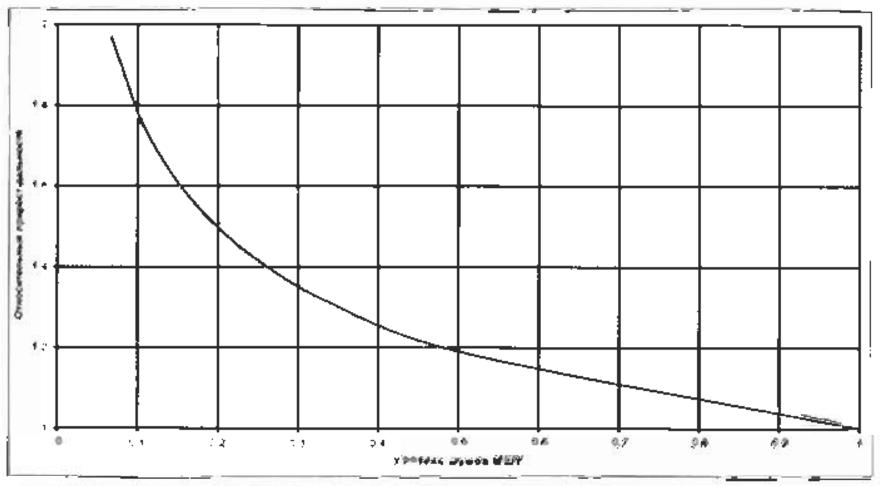


Fig. 3. Range (relative) vs. LNA noise mitigation

Several beams

Some functions – looking at multiple targets etc – require scanning by several independently controlled beams. Phase synthesis seems a ready – well-tested and proven – solution but its implication is that the gain in each beam becomes lower, which does not work when the pilot needs to track, for example, two targets simultaneously in a monopulse mode. If the array generates two outgoing beams, the power is lost and, more importantly, the response signals from both targets will not be split because splitters use frequency and radiating two beams at different frequencies is impossible.

So, the only way to track two targets simultaneously is to make the tracking signals, strictly speaking, non-simultaneous. However, even in this case the splitting will not be clean because the incoming traffic on the transceiver would have to be first split into two frequencies (losing power) and then processed separately by separate units: two distributors, two comparators, two simultaneously working receivers and two input ports and processing units for simultaneous signal processing. Sounds too cumbersome.

There is a very promising option – multi-channel digital processing of the signal coming from a modular active phased array. This is a system with two-level phasing: primary (module-level) phasing by the transceiver in the aperture and secondary (inter-module) digital phasing. The idea is that there is no loss during processing because the signal is split after it has been converted

Fig. 4. Gain drop vs. beam deflection angle

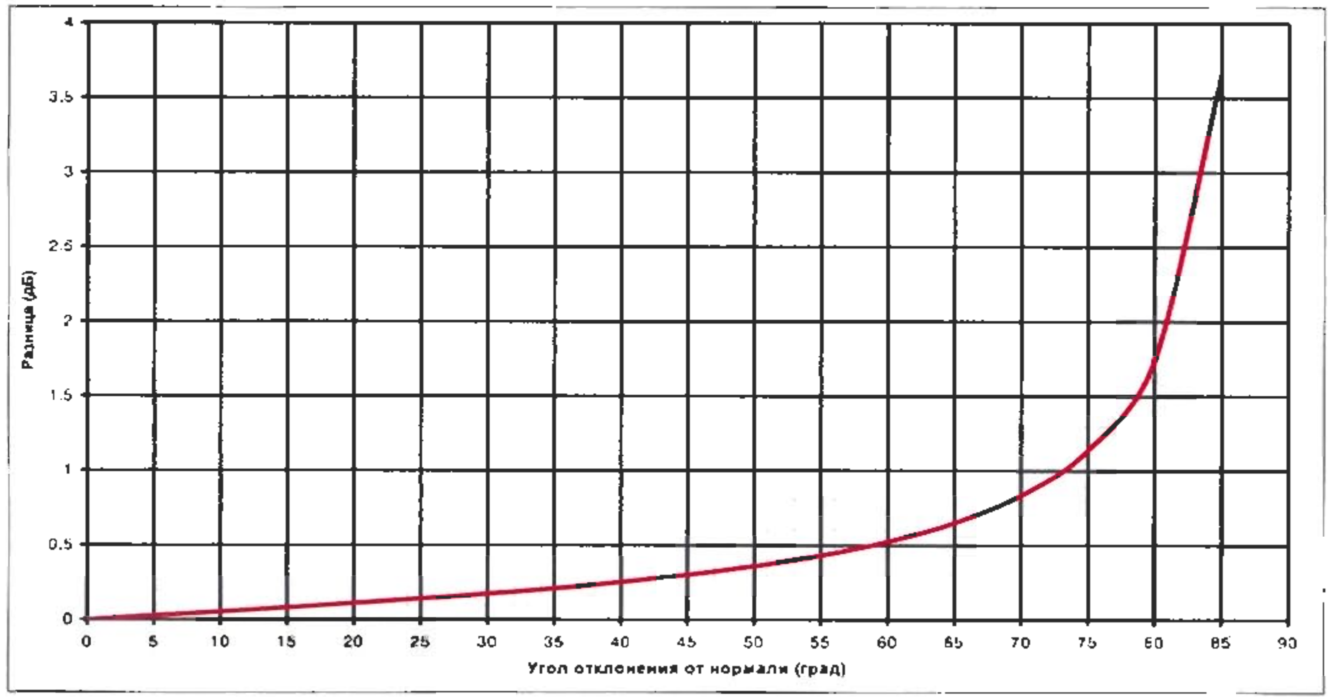


Fig. 5. Difference between directional pattern maxima vs. beam deflection angle

into a digital form. Digitized general signals from each module come to the digital inputs of the multi-channel processing unit. Here they are not yet split, similar to primary processing analog systems.

Admittedly, there are also many challenges. All the array modules (sub-arrays) must be of the same configuration so that they all make equal sections of the aperture, each of which is connected to a transceiver group. The distribution of UHF power inside the modules should offer minimal loss between the elements, and the gaps between the sub-arrays must be as narrow as possible. In such a system, reference signal coherence and incoming local oscillator signal become a problem; the main lobe must also cover the whole area in which the multiple targets are located.

Yet, the end is realistic and does justify the means. An additional benefit is that such a system can cut off jamming in an adaptive manner, even if the jamming source is located near the target or even within the main maximum of the directional pattern.

This method has been validated by numerical simulation and is currently pending practical tests. We expect to prove that a modular active phased array with a multi-channel digital receiver is the largest intermediate step to a fully digital array of the future. ●

X-band active phased array: scope of work report

Alexander Dolgachev – head of section, Phazotron NIIR Corporation

Complicated and innovative radio systems – and active phased arrays for onboard radars are one of the most difficult – present many technical and conceptual challenges that must be properly addressed before the first experimental radar can be built. Therefore, our development strategy relied on several basic principles:

- look at the broad picture – try to see how the system is going to work throughout the radar's lifecycle;
- preserve continuity in the development of hard- and software – try to make a radar that will be able to learn new functions;
- concentrate all resources on key development issues;
- use as much as possible from traditional PA and radar technology.

Below we will consider these guidelines in more detail in the context of the main development milestones:

- the shape of each radiating element and their accommodation on the array;
- radiating curtain configuration;
- transceiver cooling;
- upgrade options and insight into future radar technology.

By "looking at the broad picture" we defined the need to design this or that feature, considering all manufacturing, operation, and forthcoming maintenance issues. This means that before formulating requirements specifications for this or that subsystem, we considered power limitations, cooling opportunities, possible transceiver/computer interface settings, and built-in self-check (radar and separate modules) capabilities.

To "concentrate resources on key development issues," one must determine these issues first. This is where our third principle – "use as much as possible from traditional technology" – is at work. One needs to analyze everything done so far in this line of inquiry and concentrate only on questions that the existing technology has yet to answer. This saves time, money, and effort and allows the team to concentrate on what is really critical for the new design. Another way to make the designing process more cost-efficient was the adoption of previously tested design methodology and extensive use of numerical simulation.

The adaptation of previously built units can involve as much numerical – and as little real – tests as possible, but this does not work for new units that have never been tried in practice. The reasonable approach here is to begin real tests from the early stages of design, saving all information and results for numerical analysis. As data pile up, their amount becomes sufficient for numerical tests at later stages, which means more numerical simulation can be used, with all the benefits it implies.

The same approach applies to the use of old and new elements in designing a new system. In our case, we took the distribution system, built on a reliable radial waveguide distributor, from the traditional radar. The other element taken from the previous design was the large-angle radiating element providing electronic scanning of a 120-degree cone. This saved us time and effort, so that we could concentrate on other issues, at the same time testing alternative solutions improving the operational bandwidth, the scanning angle, and the UHF distributor efficiency.

Considering the underlying principle of radar upgradability and unification, we needed a consistent vision of future issues radars might face after the first off-the-shelf solutions enter operation. This requires very special analysis and results in lists of possible issues and possible ways to address them. One needs to be a practical as well as theoretical specialist to perform such analysis because they also must formulate, on the basis of theoretical findings, new requirements to problem-solving equipment and methodology: how will we test experimental performance or change the settings of separate subsystems and of the system as a whole? which methodology is best to measure progress and compliance? will the existing measurement equipment and methods work or will we have to devise something completely new? This is just the tip of the iceberg of questions such an analyst confronts.

We started with the numerical simulation of the entire system. Key to it was the accommodation of radiating elements inside the aperture. In the first models, we played with one-channel transceivers but later found that four-channel transceivers with longitudinal UHF signal distribution and transverse heat exchange would be more energy-efficient and easier to cool and control. This is the most effective configuration but it leaves few options as to the aperture structure because monopulse target location is effective only when the aperture is symmetric relative to the two orthogonal axes. With traditional triangular accommodation of radiating elements, it undermined performance.

Although the new aperture structure (see Fig. 1) was devised using numerical models tested on the previous arrays, Figs. 2 and 3 show graphically that the directional pattern they have generated is very efficient and meets all the key requirements:

- max level of the first sidelobes is -30 dB;
- the average level of background lobes is -50 dB;
- directivity drop with the beam at the sector edge is -4 dB;
- the diffraction lobe in the visible range at any beam position within the scanning sector is non-existent.

The numerical simulation of the impact of amplitude/phase control precision upon the pattern quality suggested that a five-bit system would do for the amplitude and a six-bit one for the phase – perfectly realistic precision adopted by most international active phased array producers.

The transceivers in the radiating curtain are being powered and controlled linearly: the controlling codes and commands always go along the same

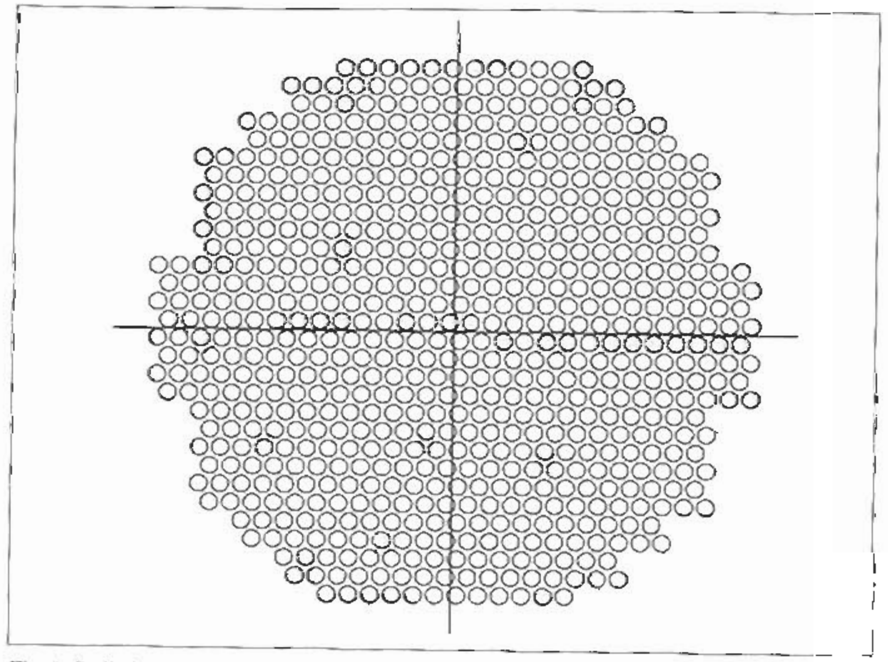


Fig. 1. Radiating elements accommodation

bus but contain the number of the destination transceiver, so that others are not affected by the command. Meanwhile, HF signals are distributed by a parallel scheme built on a waveguide distributor. This distributor consists of a radial waveguide with a monopulse output comparator and a set of coax–ial/waveguide switches whereby the transceivers are connected to the distributor.

The system powering the key pulsed output transceiver cascades was a particular problem. To secure stable power voltage, a special capacitor sits on the power distribution bus near each transceiver. With voltage stability thus ensured, we can minimize the transceiver power loss during the pulse.

The transceivers are cooled by the frame they are installed upon. Each transceiver base is in fact a cold plate with a liquid coolant inside, tightly pressed to the transceiver. The plates take the coolant from the input collector and drive it into the output collector on the other end. During operation, a temperature sensor inside each transceiver sends signals continuously to the computer, and if overheat is determined, the computer turns the transceiver off until it cools down to an adequate temperature.

Currently adopted transceivers have the following parameters:

- radiating power per channel – 5 W
- output gain – 34 dB
- input gain – 30 dB
- input noise – 2.5 dB;
- phase shift increment – 5.625°;
  amplitude shift increment – 0.7 dB;
  amplitude control range – 24 dB;
  output channel efficiency – 25%.

Each four-channel transceiver module consists of four channels controlled independently through a common system that uses module and channel addresses. Channel imperfections are hardware-compensated, which ensures that all output amplitude-phase curves are identical at any frequency and amplifier temperature. The transceiver cooling system has successfully passed all tests on thermal mockups; later its performance was confirmed by the temperature sensors of live transceivers (the sensor measures the most critical output cascade).

All transceiver channels are fully and correctly controlled, so we can be confident that there will be no problem with the transmission/reception amplitude-phase distribution over the aperture. Thus, we can suggest that numerically simulated directional patterns match with real ones precisely enough (see Figs. 4, 5 for transceiver photos).

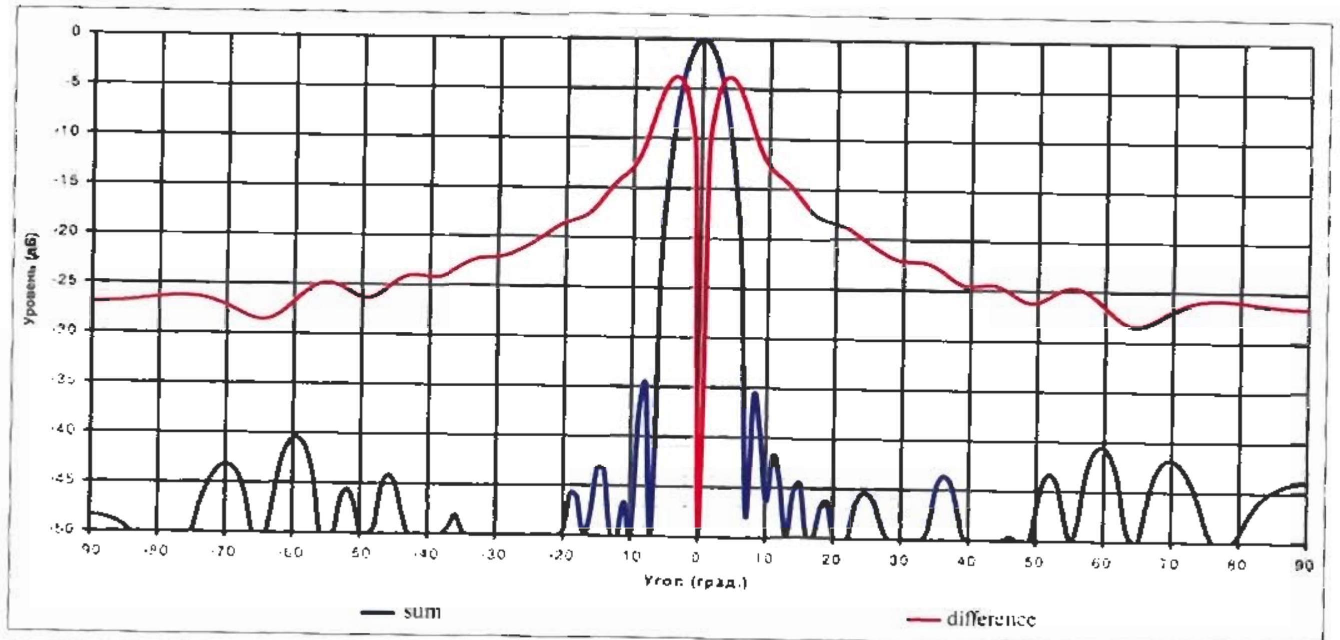


Fig. 2. Calculated difference and sum patterns

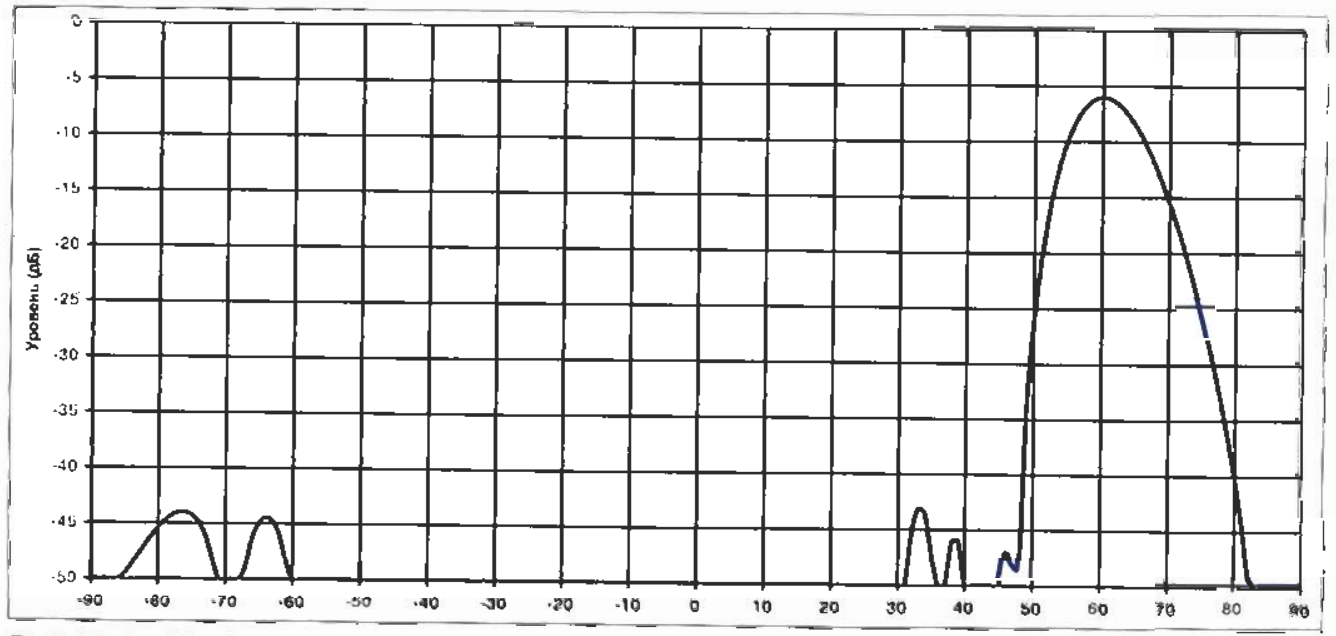


Fig. 3. Calculated directional pattern as the beam is deflected to the sector edge in the critical plane

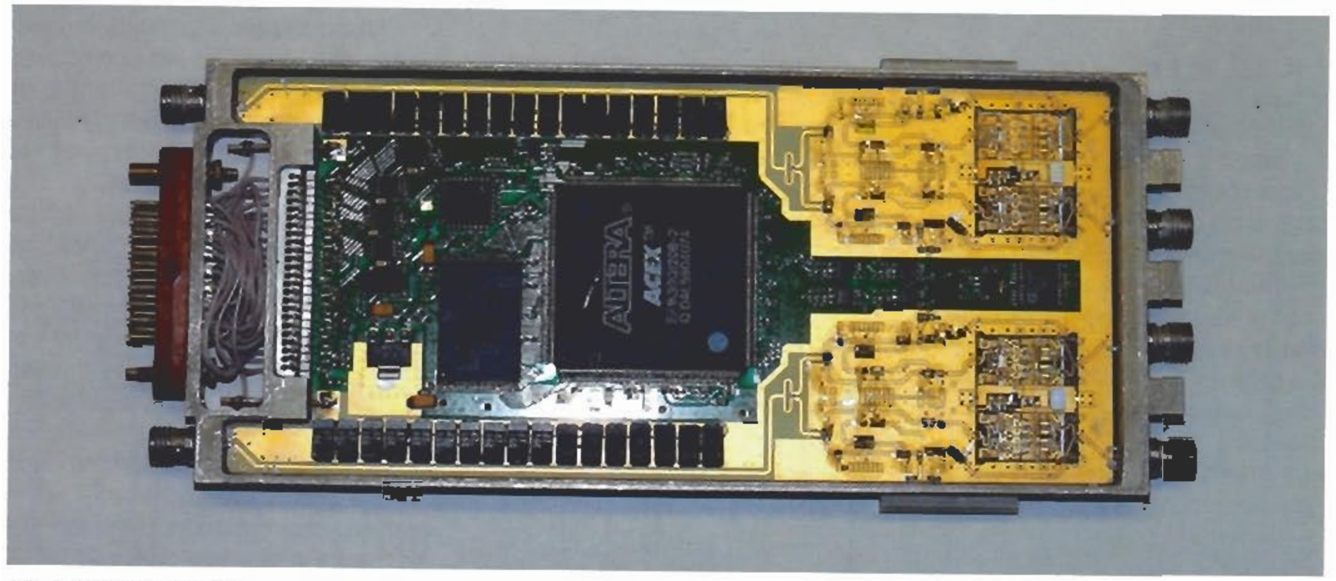


Fig. 4. Transceiver opened

After this milestone, we developed the pre-amplifier. Its job is to amplify the signal coming from the master oscillator to ensure that the transceivers, via the waveguide distributor, receive a signal powerful enough not to be distorted at the output. The pre-amplifier includes as many channels as there are in the transceiver module, all of which feed their signals to the common output where pulsed output power (up to 20 W) is controlled. The amplifier has a built-in cooling channel integrated into the radar cooling system and is controlled through the same interface and by the same protocol as any of the transceivers. It is powered through the same network as the transceiver but the power voltage comes through a separate port, and thus does not affect its control circuits (see

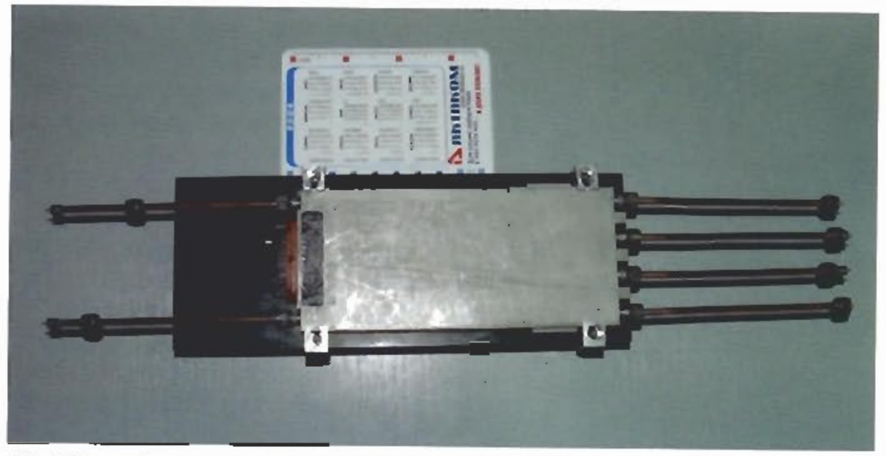


Fig. 5. Transceiver with test adaptors

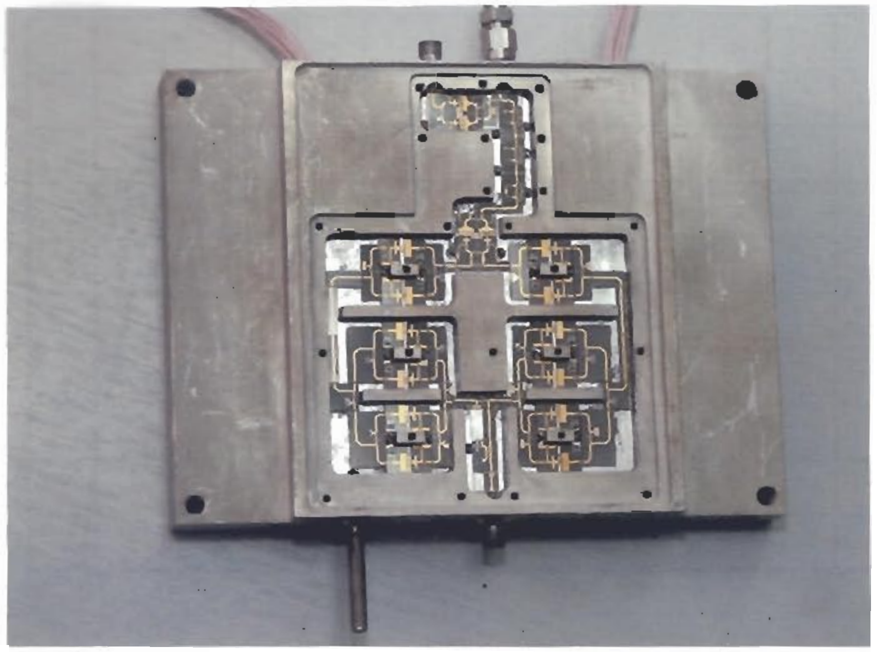


Fig. 6. Power amplifier opened (view from amplification cascades)

Figs. 6, 7 for amplifier photos: Fig. 6 – looking from the UHF amplifiers, Fig. 7 – looking from the controlling chip).

Testing and settings also present very special challenges. Many elements of an active array cannot be tested in the same way as in previous passive arrays because the transmission is pulsed and requires appropriate measurement techniques. Measuring the amplitude is easy because it is generally linked to the average signal level, but phase measurements are impossible without a new generation of instruments supporting continuous or long-period operation.

Currently a special pulsed measurement set-up for pulses no shorter than 200 nsec has been completely tested, and the credibility of its findings is beyond question. It is a PC-controlled monobloc (see Fig. 8 for a photo) with a signal generator, a transceiver control emulator, and a set of digital receivers. This multi-functional measurement suite can also test radio devices within a certain waveband and take the noise and spectrum curves of UHF devices. The suite does not require a highly qualified operator: all its functions, including the processing of the findings and automatic correction of the transceiver's gain-phase patterns (primary transceiver calibration), are fully automated.

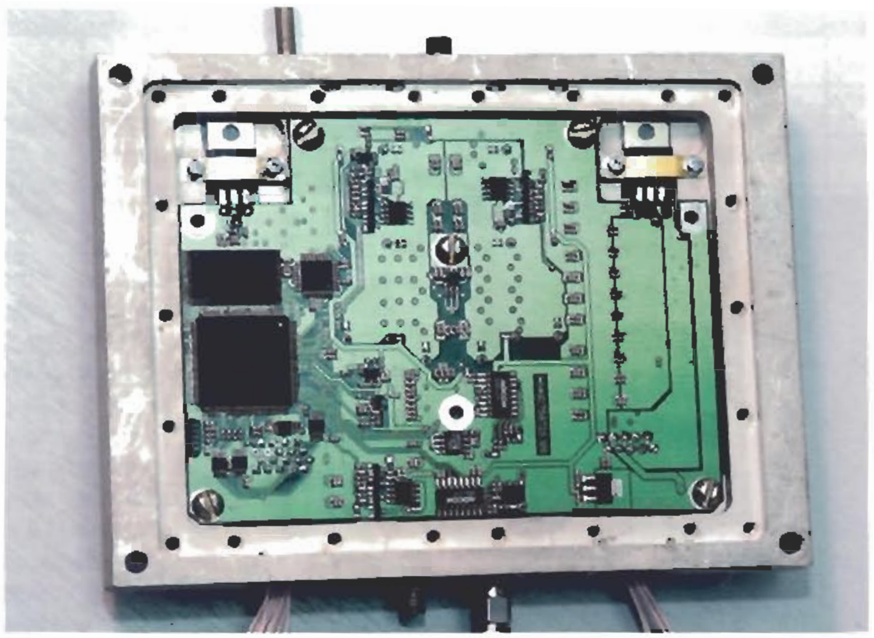


Fig. 7. Power amplifier opened (view from control chip)

Figures 9–11 show the results of a transceiver channel performance correction: Fig. 9 demonstrates how the transceiver's phase errors have been corrected, so that they do not exceed the required three degrees, without changing the attenuator's controlling code; Fig. 10 shows how the imperfection of the controlled transceiver attenuator is corrected (phase distortions are compensated as the signal amplitude is regulated); Fig. 11 demonstrates the comprehensive correction (non-linearity and attenuator/phase inverter imperfection), with the result shown as a time graph in the polar reference system over the full signal range (the amplitude is constant).

Measurements are also a problem when the array is assembled and undergoes final settings, which is basically the measurement of initial conditions for the entire set of transceivers in the aperture.

Transmission amplitude-phase distribution is the most difficult to measure because the UHF signal is very powerful (5 W per channel) and therefore hazardous. Operators are not allowed into the room during measurements in which the calibrated signal comes in through the collective input and the analysed signal is recorded by the external sensor installed on the normal line to the centre of the aperture at the pre-determined distance from it. The transmission signal is generated by only one measured channel, others are silent. Remotely turning on one radiating element after another and silencing others, operators get transmission gain measurements from each element, combine them, recalculate with additional spatial phase shifts, and thus recover the true amplitude-phase distribution.

This is direct measurement. In an alternative methodology, two elements are turned on simultaneously, and the sensor records their common signal. Knowing that the signals are anti-phase and of the same amplitude, one can change the controlling codes of one of the channels to minimize (preferably nullify) the resulting signal recorded by the sensor. If one does the same for all

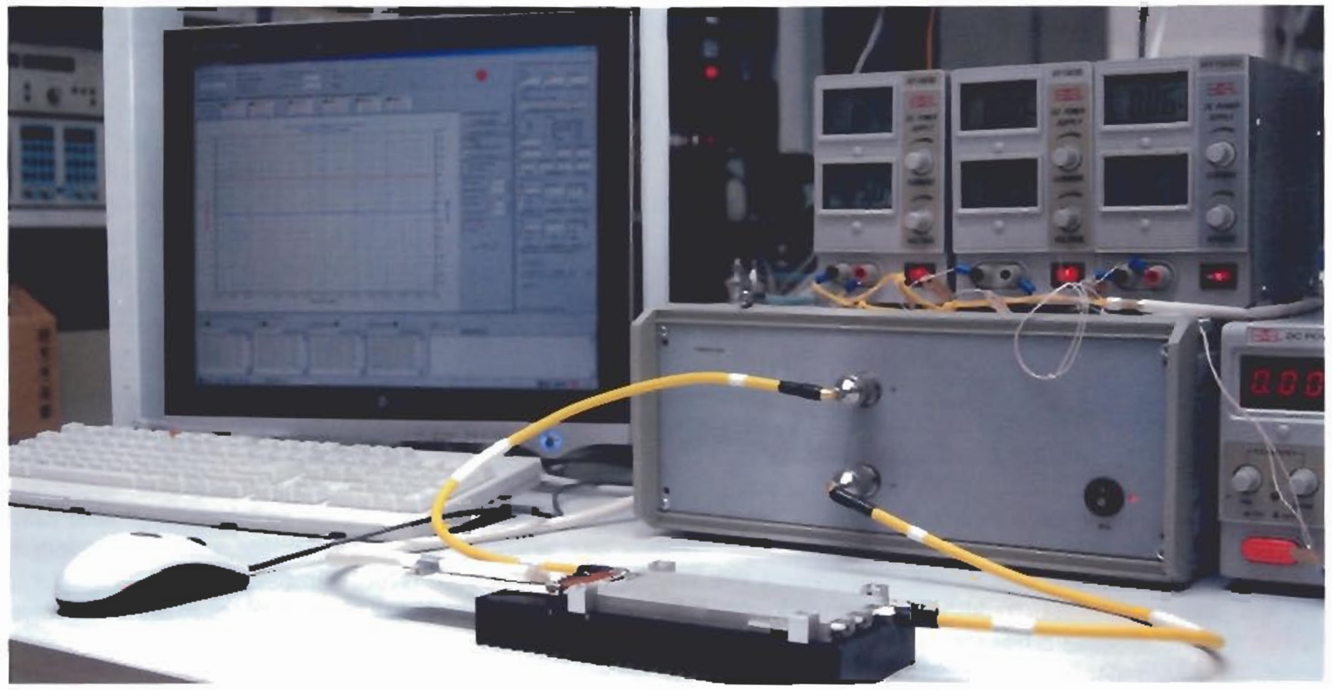


Fig. 8. Transceiver measurement set-up

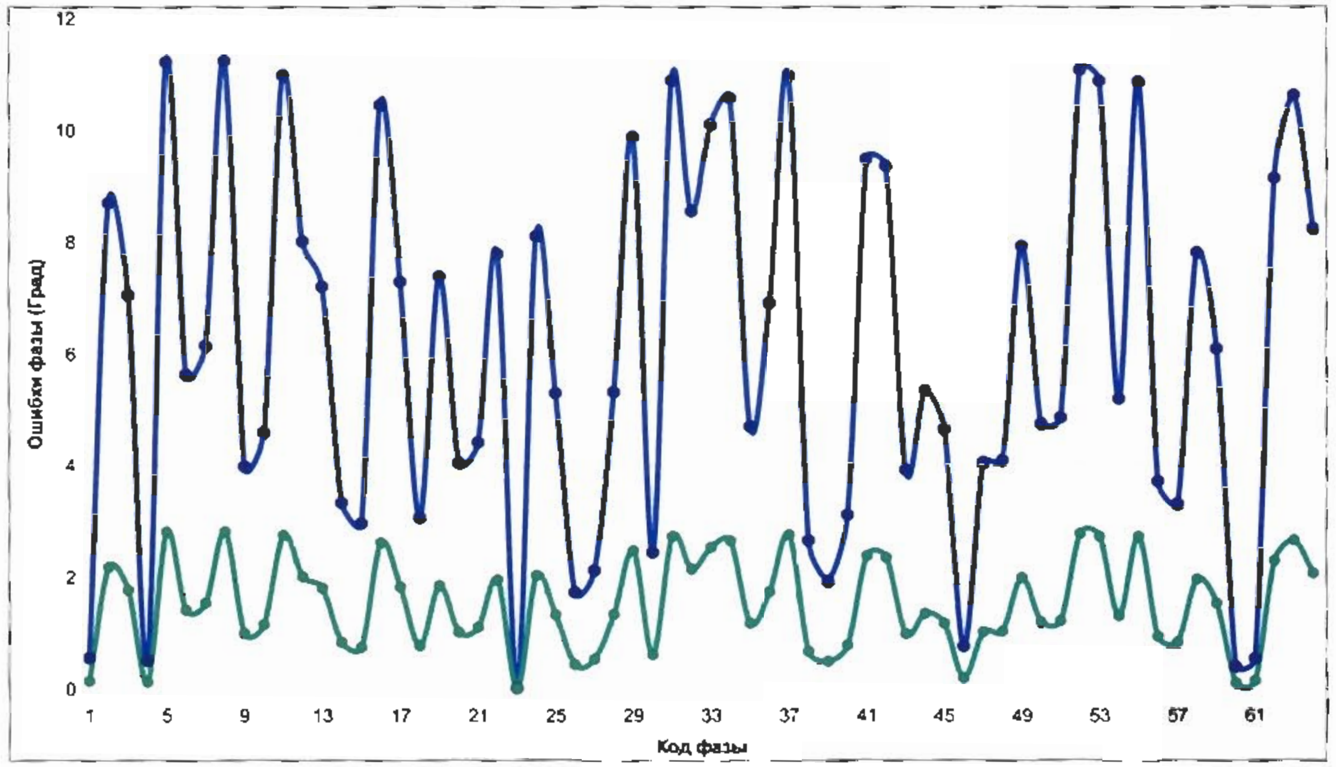


Fig. 9. Transceiver phase error correction without changing the attenuator's controlling code

the channels, the result will be a controlling code distribution ensuring the perfect (with minimal error) phase balance over the entire aperture. This method has worked well with passive arrays: the directional pattern matched the one predicted in a numerical experiment and the one recorded in a direct measurement session; phase errors were within the tolerance.

All this suggests that Phazotron has successfully developed a working active phased array radar. Now that we know such a radar is possible, however, so many new opportunities are opening up, which may so improve its performance (the limits of which, frankly, have yet to be adequately determined) and the operation of its core modules, that it is crucial to look into them before making any choices as to what to do next.

Also, we have yet to finalise a coherent methodology of the designing process for such radars. We need to know how to assess performance throughout its lifecycle and must explore other very promising options concerning configuration, cooling, and data processing. As to the latter, the

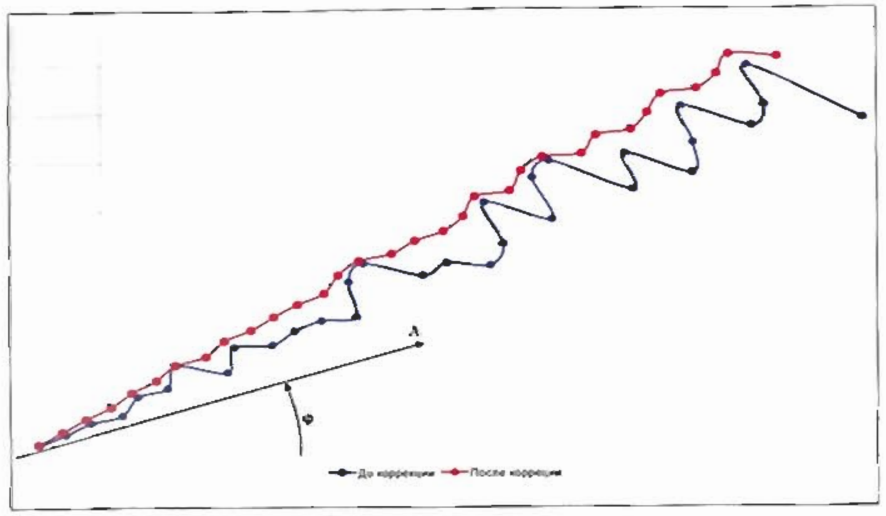


Fig.10 Phase distortion correction by signal amplitude

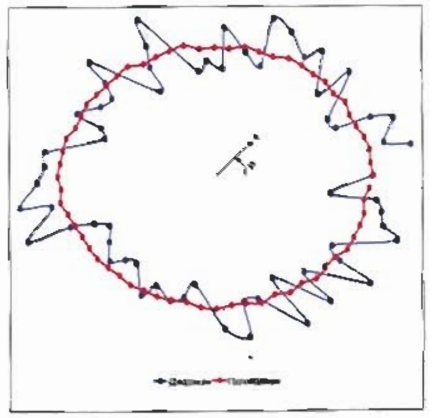


Fig. 11. Comprehensive attenuator/phase inverter correction

tested radar used the firmware written for the receiver of the traditional design and for mechanical scanning, while the APA radar uses a multi-channel receiver and electronic scanning. This suggests that more advanced firmware applied to the same experimental radar could critically enhance performance due to greater processing flexibility.

We are also looking at systems with electronic beam control, testing a passive array and creating a database for future use with an active array. We already have test findings for the large-angle emitter, the distribution system with a monopulse comparator, and core beam control algorithms (including those used to generate beams of special shape), and are currently testing polarization switching, automated radar setting algorithms, and a methodology to record directional patterns without a need to use costly collimators and swivel devices.

Other, more practical, algorithms, such as target detection and tracking and seamless operational mode interchange, are being tested using in-line simulation. Simultaneously, the experimental radar is undergoing flight tests. ●

As Russian industries are increasingly advancing chipset technology for active phased arrays, Phazotron has led a new research effort into packaged chips crucial for radars using APAs. Admittedly, these chips restrict the dimensions of the trans-ceiver, a key element of an active phased array – and therefore compromise radar performance to an extent – but the production expertise and procedures can be extensively used in future efforts to develop non-packaged chips.

Yury Guskov – deputy CEO and deputy designer general, Phazotron NIIR Corporation

Compact amplitude/phase control module for X-band active phased array transceivers

Edger Semyonov – Director General, ZAO NPTs Almaz-Phazotron
Alexander Buterin – Chief Designer, laboratory head, ZAO NPTs Almaz-Phazotron
Andrei Kishchinsky – Chief Designer, ZAO Mikrovolnovya Sistemy
Vladimir Radchenko – laboratory head, Berg Radio Engineering Institute (CNIRTI)

Active phased arrays create a new approach to onboard radars, greatly expanding their functionality and making them adaptable to rapidly changing tactical environment. In such arrays, the directional pattern of the transmitted and received beams is shaped by the right choice of amplitude-phase distributions in the radiating curtain. These distributions are implemented by attenuators and phase inverters. Both are part of a digitally controlled transceiver with an access time of several nanosec-onds. These devices need to be, on the one hand, advanced enough to shape quality patterns and precisely set UHF signals, and on the other, compact enough to

install them in an aircraft, where space is critical.

In the modern world, only highly integrated chips can provide such per-formance, and the national development of chipsets in Russia has for a long time been a major headache for active phased array radar producers and for the national electronic sector as a whole.

Almaz-Phazotron has been working on the transceiver and its chipsets since 2000, completing a core element – the multi-bit digital attenu-ator/phase inverter (API) which compensates the UHF signal loss to con-trol the array patterns in 2006 – the first transceiver chip of a fully Rus-sian design. The key results are presented in the article below.

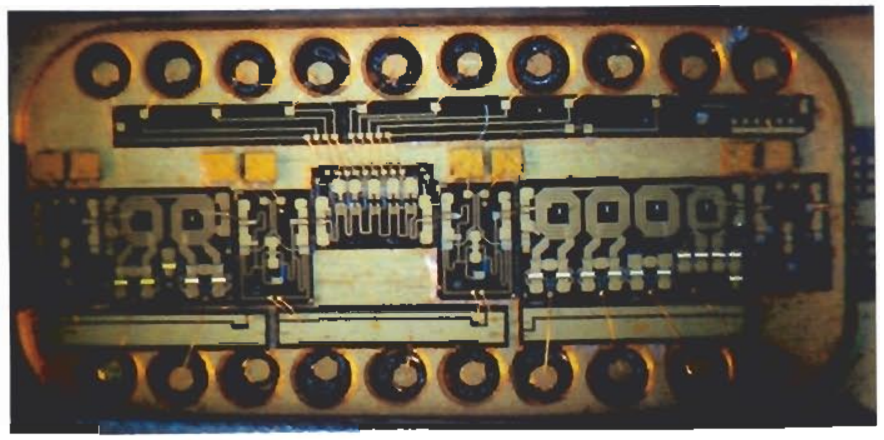


Fig. 2. Crystal set

Purpose and configuration

The API works as part of a ground- or aircraft-based active phased array radar transceiver. It is a 2-g 8x22.5x2.5-mm module with micro-strip UHF input and output, protected by a mono-bloc case (Fig. 1) which has special ports for control signals and power. The module is very easy to install into a transceiver, which is important, especially at the current testing stage.

The functionality includes five-bit control of UHF insertion attenuation (0 dB to 31 dB); six-bit control of the UHF signal phase (0_ to 360_); and UHF loss compensation in the controlled bits. It provides the linear output powe- of 10 mW, enough to build up the pre-amplifier in the transceiver's transmitting channel. The attenuator and phase inverter are controlled by parallel 15-bit binary code (0 V and –5 V, maximal access time 6 ns).

The module includes a set of GaAs crystals on metal substrates (Fig. 2).

In fact, the GaAs crystal set was the most significant problem. Seven crystals of four types are at work: one five-bit attenuator (increment 1 dB); one four-bit phase inverter (increment 22.5°); one two-bit phase inverter (increment 5.625°); and four buffer amplifiers (Fig.2), connected to power and control buses by intermediate GaAs chips. The power circuits of buffer amplifiers include ceramic chip capacitors. All elements are in-stalled using conductive adhesive and gold wire micro-welding.

The GaAs crystal

The attenuator is based on the following basic elements:

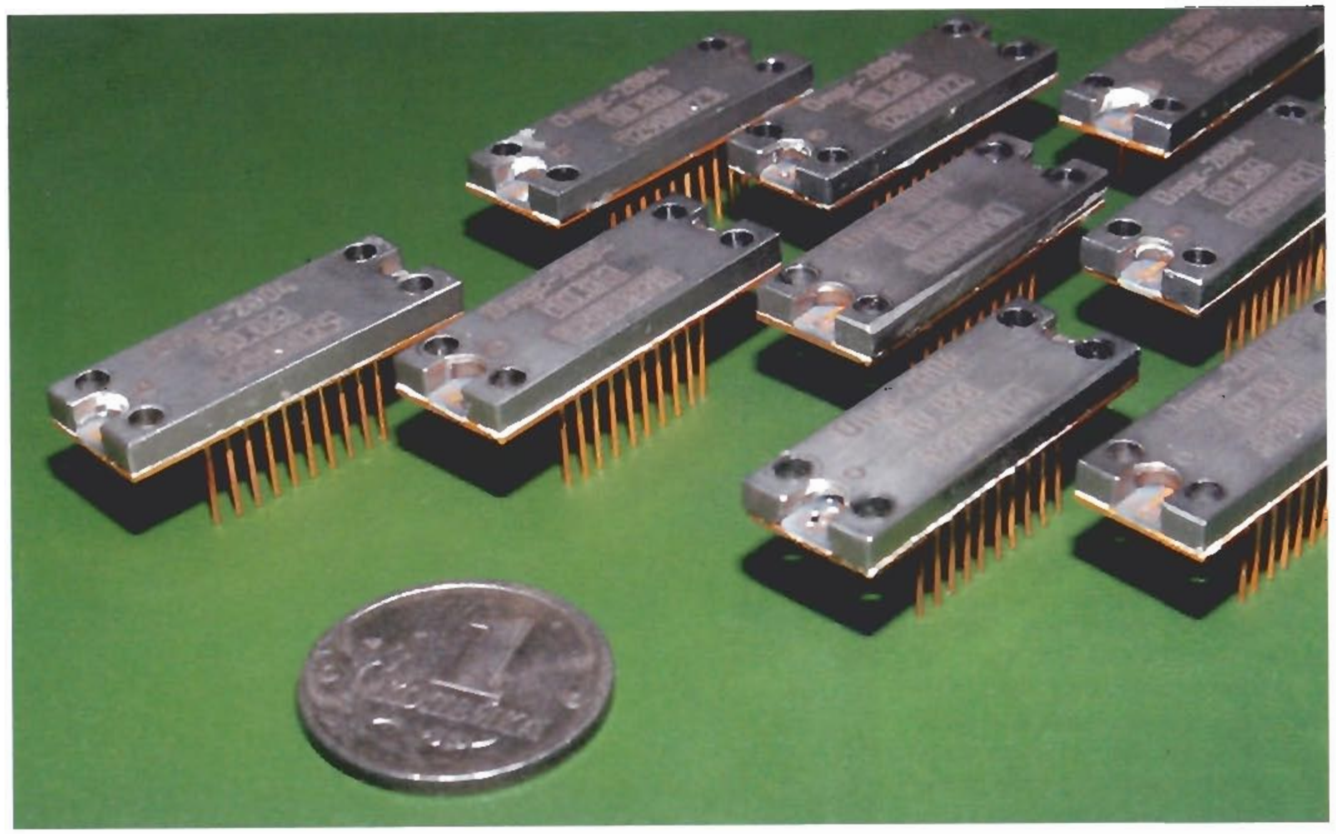


Fig. 1. API module

- the junior section (1 dB) is of very simple design (a resistor parallel to key transistors);
- the senior section (16 dB) consists of two sequential 8-dB subsections to mitigate the attenuator's total vulnerability to the imperfect match between the parameters of resistive films and transistors;
- the distributed thin-film resistive attenuators have a surface resistance of 50 Ohm/square;
- all topologies are analysed by 2.5 D electrodynamic simulation software before production.

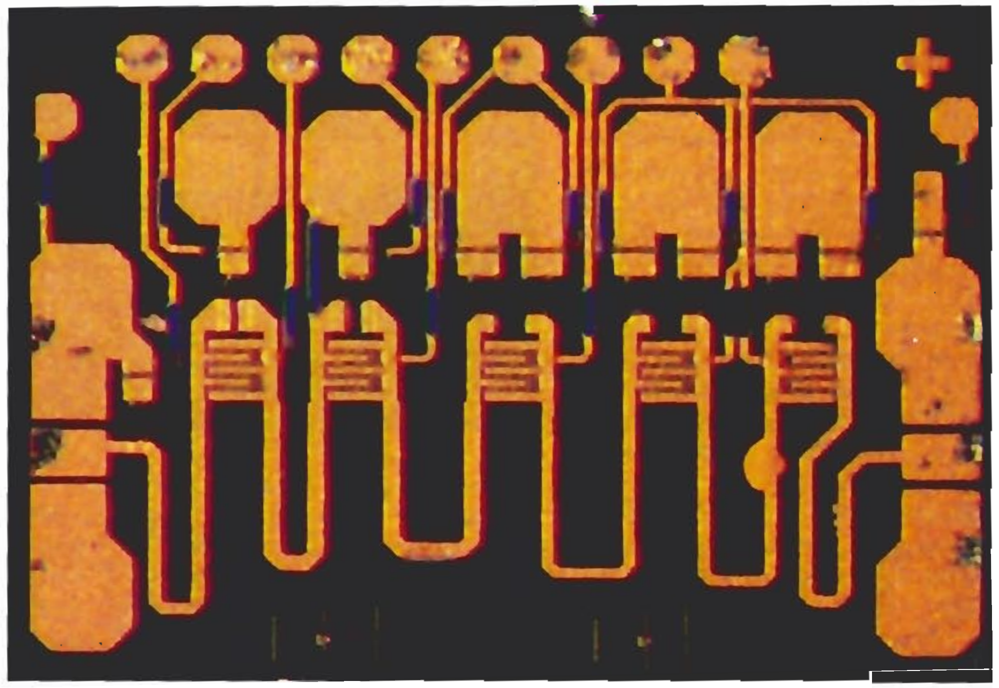


Fig. 3. The five-bit attenuator GaAs crystal

The attenuator is made on a 2.1x1.6x0.1-mm crystal with 50- to 300-mcm Schottky transistors as key elements (Fig. 3). Sections are linked by micro-strip lines to mitigate the input/output voltage standing-wave ratio. The resistors are made of the 50 Ohm/square tantalum film.

According to the experimental studies of crystal samples, the attenuator controls the UHF signal amplitude between 4 GHz and 14 GHz (Fig. 4) with the root-mean-square error of no more than 0.5 dB between 4 GHz and 11 GHz and the insertion loss of 8 dB to 10 dB.

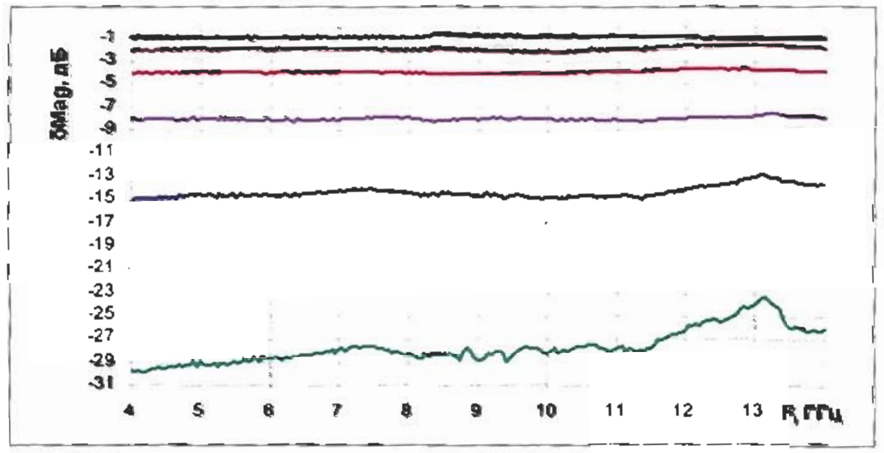


Fig. 4. Typical amplitude-frequency response of the insertion loss of the various bits in a five-bit attenuator GaAs crystal

The phase inverter GaAs crystals

Most phase inverters on GaAs use high- and low-frequency switched filters whose huge minus is the difficulty to realize the 180 and 90° bits. They make less use of directional coupler-based circuits and Lange couplers because it is very difficult to produce enough such couplers with the right topology and ensure minimal insertion loss there. We used a folded directional coupler on a 100-mcm GaAs substrate. It is smaller and has less loss than a Lange-based system.

The phase inverter was designed using the MIC Optimizer computer simulation package (with parametric optimisation) with fine-tuning electrodynamic simulation in the final stage.

The phase inverter is made on two crystals (Figs. 5, 6). The 4x2x0.1-mm crystal of the four-bit phase inverter includes the 22.5, 45, 90 and 180° bits, leaving the 5.625° and 11.25° bits to the 2.5x2x0.1-mm crystal of the two-bit phase inverter. The two-crystal scheme is needed because of low cost efficiency of large-area crystals.

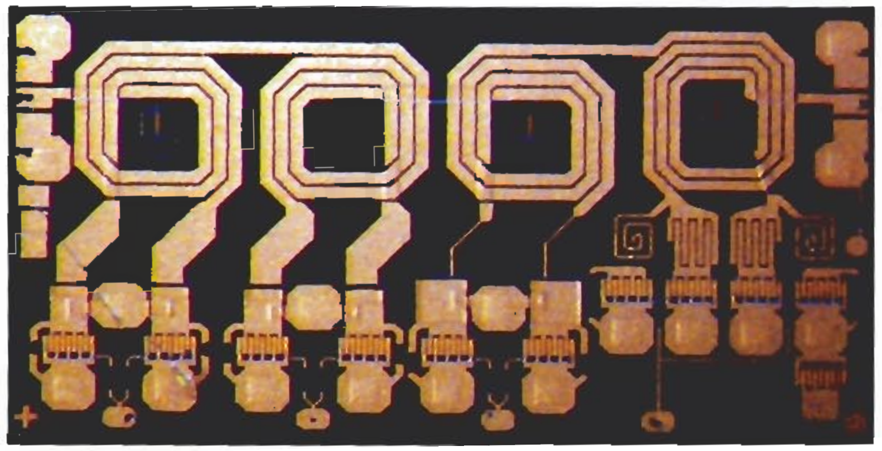


Fig. 5. The GaAs crystal of the four-bit phase inverter (22.5, 45, 90, 1800) bits

The MDM capacitances in the arms of the folded directional coupler are made by gold spraying and cathodic electrodeposition, wit the 0.4 mkm SiO_2 layer used as the dielectric. The key elements are 600-mcm Schottky transistors. To mitigate incidental amplitude modulation, the phase inverter has bypass resistors equalizing loss in different phase states.

The advantage of such a phase inverter is that it is far less sensitive to crystal quality that traditional designs on frequency filters, which increased the good-to-bad ratio, and uses unipolar control, which makes the design much simpler.

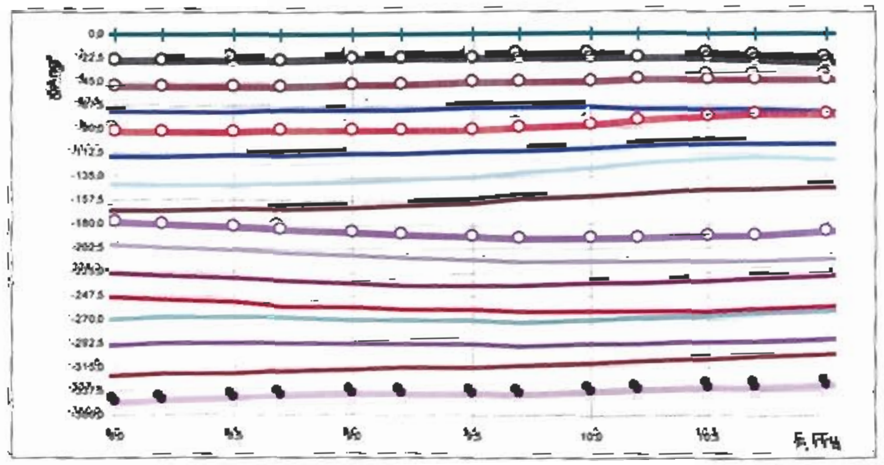


Fig. 7. The typical phase frequency response of the GaAs crystal of the four-bit phase inverter in all phase states

This phase inverter has been proven experimentally to ensure reliable UHF signal phase control between 8 GHz and 11 GHz with the root-mean-square error around 6°. Figure 9 exemplifies by the phase frequency response of the GaAs crystal of the four-bit phase inverter. The 180° bit has the highest frequency irregularity; it is going to be mitigated in an additional topology improvement effort. Other planned improvements include the UHF loss reduction in the crystals from the current about 2.5 dB per bit to 1.5 dB to 2 dB per bit and of the root-mean-square error to 2 to 3°, and broadening of the bandwidth to 4 GHz.

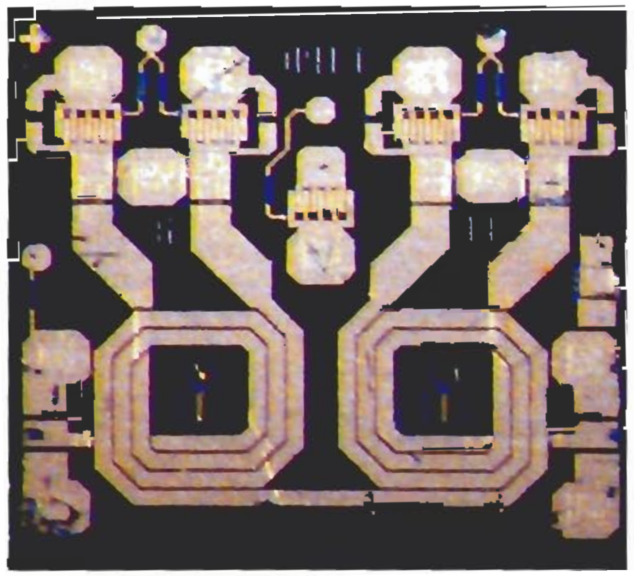


Fig. 6. The GaAs crystal of the two-bit phase inverter (5.625°; 11.25°)

The buffer amplifier GaAs crystal

The buffer amplifier compensates UHF loss in the attenuator and phase inverter crystals and helps align crystals in the chip assembly and module in the transceiver.

This is a one-cascade amplifier on a 1.3x2x0.1-mm crystal, with negative feedback provided by a 300-mcm Schottky transistor. Between 8 GHz and 11 GHz, the amplifier achieves the gain of 7 dB to 9 dB and linear output power about 10 mW while it consumes maximum 20 mA at 5 V.

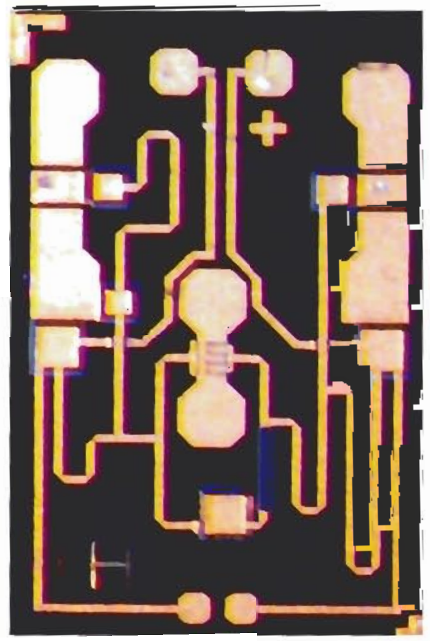


Fig. 8. The buffer amplifier GaAs crystal

Key API parameters

The API module controls the UHF signal insertion loss in 31 steps (Fig. 9) and insertion phase shift in 63 steps (Fig. 10). The typical measured RMS errors between 8 GHz and 11 GHz are 0.7 dB and 9° for the attenuator and phase inverter, respectively.

The amplitude and phase controls have shown satisfactory dynamic band, discreteness, and access time which ensures the required amplitude-phase distributions in the radiating curtain for the main operational modes of an active phased array. The system shapes a directional pattern, successfully suppressing sidelobes, ensures spatial beam scanning etc, though there is some room for improvement in the phase inverter errors.

The module did not demonstrate as precise attenuation settings as the crystals themselves: while the attenuator performance hardly changed, the first phase characteristics were much worse than expected. This was caused by the high sensitivity of the phase frequency response to the chip alignment quality affected by wire links, the key deficiency of this production technology. Additional elements responsible for the alignment would not have helped because other difficulties would have arisen: ensuring alignment within a broad bandwidth would have required additional module setting procedures. In commercial production, this would have decreased the good-to-bad ratio, driving up labour and overall costs dramatically.

This is a very typical example to demonstrate the importance of the right packaging for GaAs crystals for technological as well as economic reasons. In the next stage, we plan to adopt LTCC и MCM-D packaging.

The incidental amplitude modulation does not exceed 1 dB for the whole module thanks to special solutions to equalize transmission gain in different phase states of the phase inverter bits.

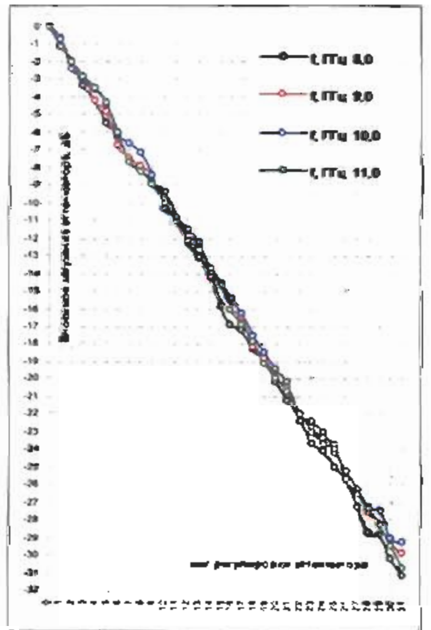


Fig.9. The API insertion loss experimental characteristics in all 32 attenuator states (8 GHz to 11 GHz)

The maximal incidental phase modulation of the attenuator bits at 1 dB, 2 dB and 4 dB is 5° between 8 GHz and 11 GHz (Fig. 11). The higher attenuator bits (8 dB and 16 dB) do not suppress insertion phase shift well enough because of broader transistor gates and higher resistances. These adverse effects can be nullified by the appropriate

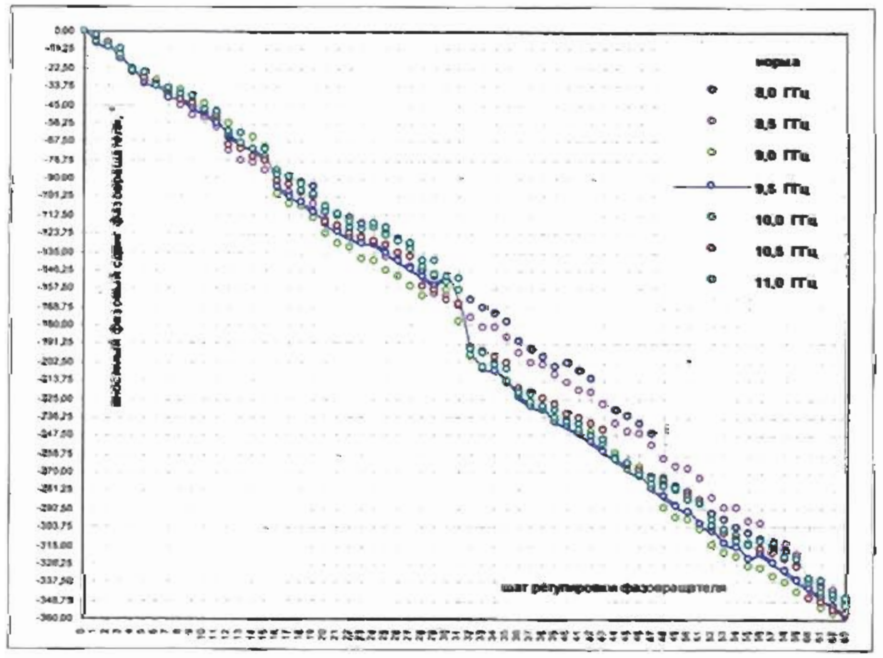


Fig. 10. The API insertion phase shift experimental characteristics in all 64 phase inverter states (8 GHz to 11 GHz)

attenuator and phase inverter settings for this or that amplitude-phase distribution.

The temperature stability of both the attenuator and the phase inverter is high, with the RMS phase change in all the phase inverter states no more than 0.6° between 20°C and 80°C and attenuator insertion loss no more than 0.5 dB within the operational heat range.

With four buffer amplifiers, each module compensates UHF loss in the attenuator and phase inverter crystals between 8 GHz and 11 GHz (23 dB to 25 dB) with the additional UHF signal amplification by 5 dB to 10 dB and ensures minimal output power of 10 mW at the 1dB compression point. The total consumed power does not exceed 80 mA.

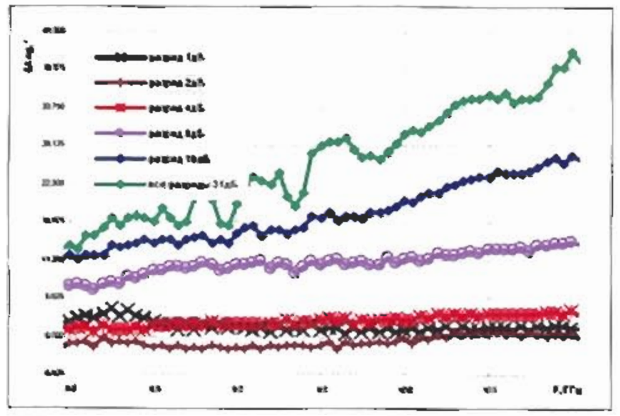


Fig.11. The API insertion phase shift experimental characteristics

Thus, a group of companies led by ZAO NPTs Almaz-Fazotron has developed the compact gain/phase control module for active phased array transceivers. The module has been prepared for production; the first batch of quality modules has been produced for commercial use.

The module, based on GaAs microchips, is of fully Russian design. It is very insensitive to inevitable imperfection of commercially produced items, which ensures high good-to-bad ratio and low production cost.

The technologies and solutions involved form solid prospects for further research into key devices of future air-, space-, land-, and sea-based active phased array radars.

Phazotron single-basis radars

Yury Guskov – deputy Director General/deputy Designer general, Phazotron NIIR Corporation
Vladimir Frantsev – Chief Designer, Phazotron NIIR Corporation

Combat fighter aircraft are a very costly weapon, which explains why industry has been considerably lagging behind military planners' requirements. With very few new fighters currently being developed worldwide, upgrade and rearmament programs for the existing fleets become crucial for high combat performance. New smart weapons, however, require more modern onboard radars than the ones originally installed in many aircraft.

In the U.S. Air Force, three best-known such upgrade efforts are the Block 60 program of the F-16 (the APG-66 gave way to the ARG-68, which was later replaced by the active-phased-array APG-80); and similar programs for the F/A-18 (APG-65 to APG-73 to the active-phased-array APG-79) and F-15 (APG-63 to APG-70 to the active-phased-array APG-63V(2)).

Latest local armed conflicts have underscored the role of fighter jets in modern warfare as these traditionally air-confined aircraft are increasingly required to add ground assault to their missions list. Thus, what used to be an air superiority fighter turns more and more into a multirole aircraft.

In Russia, Phazotron, the leading producer of airborne radars, takes its own business approach to the issue, combining the supplies of single-basis radars for newly built or modernized aircraft with lifelong responsibility for their operation.

The basic Phazotron radars for fixed-wing aircraft, the Kopyo and Zhuk-ME, are modular, open-architecture, and based on the same set of technological solutions, which ensures maximum cost-effectiveness and minimum cost of ownership.

Originally developed for the MiG-21 BIS UPG (Fishbed) currently in service with the Indian Air Force, the Kopyo-I radar made these otherwise old-fashioned aircraft five to seven times as effective in combat as before the upgrade. Phazotron has already supplied 125 such radars to India, where they have been part of extensive upgrade programs in key air wings. The modernised Fishbeds, renamed MiG-21BIS UPG Bison, are now back in service with the IAF.

One prominent offspring of the family of single-basis Kopyo radars is the Kopyo-25, the new radar suspended outside the airframe of the Su-25TM (Su-39) Frogfoot ground assault aircraft. The radar offers the plane an all-weather day/night capability against stationary and mobile surface targets and currently, with an already upgraded computer, undergoes flight tests to become the main Su-39 radar.

The Kopyo-M, another well-known Kopyo derivative, has the same purpose as its predecessor but is based on a new chipset and has a new processing unit, thanks to which it is lighter, more compact, and more reliable than the previous version; it detects aerial targets at 25% longer range, and halves the radar map formation time in the synthetic aperture mode. This makes it suitable for light assault aircraft and combat trainers. The Su-39's Kopyo-25 can also be replaced by the Kopyo-M to increase combat efficiency. The Kopyo-M is currently undergoing flight tests.

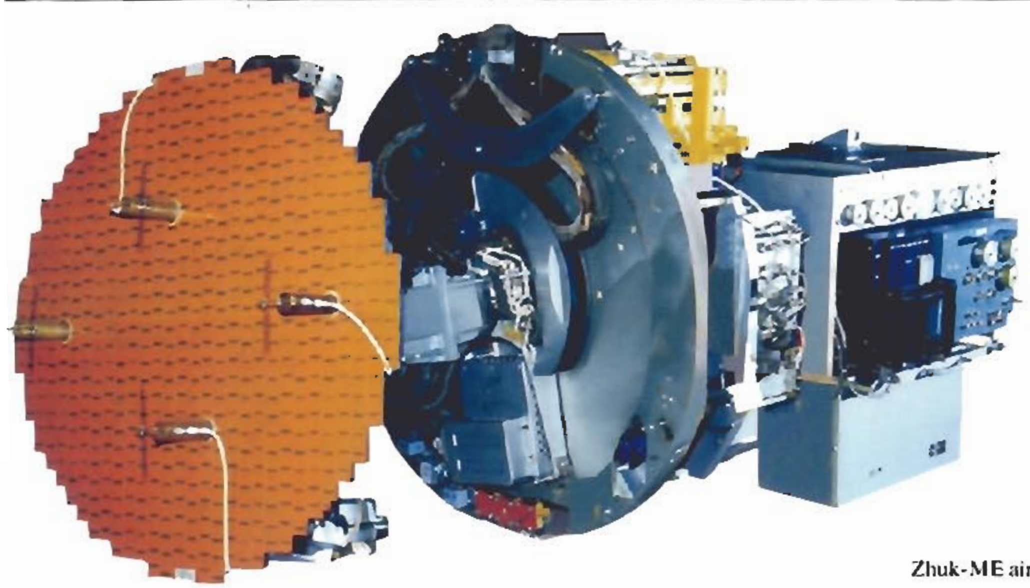
Kopyo-M's main units and technology formed the backbone of the Kopyo-A

and Arbalet radars for rotary-wing aircraft.

Helicopter radars are a high priority for Phazotron because here a better radar gives much more visible and crucial advantages: modern radars, in fact, create a new quality of helicopter warfare in joint operations with ground forces and navies, night-time operations, and action in adverse weather and visibility conditions.

The Kopyo-A is the main radar of the deck-based Ka-28 (Ka-28M) Helix helicopter. Within a circle of 360° in radius, up to 250 km in range and up to +25° in elevation, it detects all aerial objects and surface objects as small as dinghies, fast-boats, or submarine periscopes; identifies, continuously locates, and tracks up to 10 targets; and detects, locates and warns of dangerous meteorological formations.

The functionality of the Arbalet version installed on the Kamov Ka-52 Hokum attack helicopter includes terrain mapping, detection and identification of surface and aerial mobile and stationary objects, incoming missile/proximity warning, and detection/assessment of dangerous meteorological formations. It also supports terrain-following flight (recognising such characteristic surface objects as power transmission lines,



Zhuk-ME airborne radar

chimneys, towers etc) and gives target designation to guided and unguided weaponry in typical combat missions against such targets as armour and mechanized infantry units, artillery and self-propelled antitank and surface-to-air systems, grounded and airborne assault and rotary-wing aircraft, and tactical missile launchers.

The Arbalet is a two-band (Ka/L) coherent-pulsed frequency-tuning polarization-switch radar. Customized off-the-shelf options are also to include either only the Ka-band (Arbalet-K) or the L-band (Arbalet-D) system.

The Arbalet-D radar is part of a rotary-wing aircraft avionics suite and detects incoming aerial objects, including other aircraft, projectiles, and missiles. Such L-band radars as the Arbalet-D become increasingly important in a world where widespread counterterrorist warfare implies a need to protect helicopters from Stinger-class Manpads, and should be included in present and future upgrade and development plans for utility as well as attack helicopters.

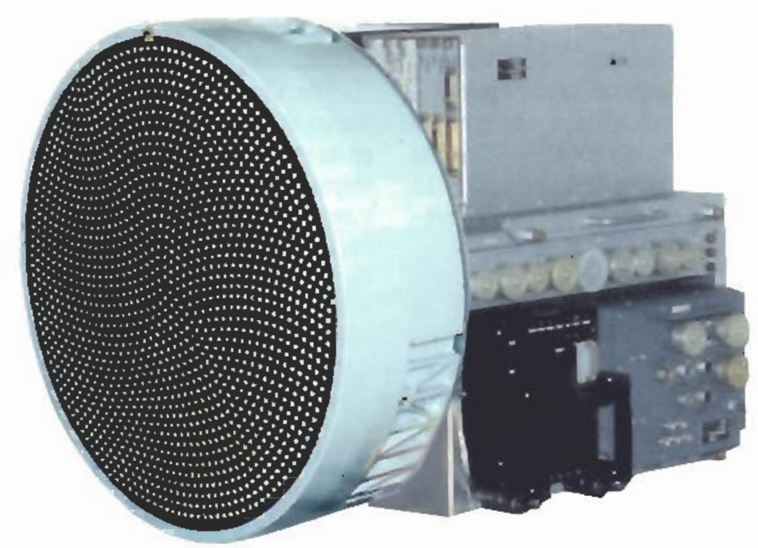
Both Kopyo-A and Arbalet have successfully completed their ground testing programs and are undergoing flight tests.

The Zhuk family was designed for tactical, strategic, and naval aviation to support full all-weather day/night navigation and combat capabilities against all types of surface and aerial targets. The family includes four radar versions having the same radio detection/ranging module and differing only in the antennas:

- Zhuk-ME – 624-mm slot-array;
- Zhuk-MSE – 960-mm slot-array;
- Zhuk-MFE – 700-mm phased-array;
- Zhuk-MSFE – 980-mm phased-array.

The Zhuk-ME is the core of the Fulcrum MiG-29/MiG-29SMT upgrade suite. With all ground and flight tests completed, it has earned a stern reputation as part of the MiG-29SMT fighter sold worldwide. A similar upgrade program of the same producer, RAC MiG, is currently nearing completion: MiG-29 to MiG-29K. 'K' in the latter name stands for 'korabelnogo bazirovaniya', or 'deck-based.' In accordance with the aircraft's purpose, the radar will be additionally fine-tuned to ensure utmost efficiency against high sea environment and provide target designation data for anti-ship missiles, although its tests at sea (as part of the MiG-29SMT) with the Kh-31A (AS-17 Krypton) missile have already been successful enough, with direct hits.

The Zhuk-MSE of the Su-30MK3 (Flanker) has successfully passed flight tests. Its announced performance was confirmed in flight tests in 2004: the Zhuk-MSE ensures efficient employment of all operational and near-term air-to-air and air-to-surface Su-27/Su-30 weapons in any tactical environment.



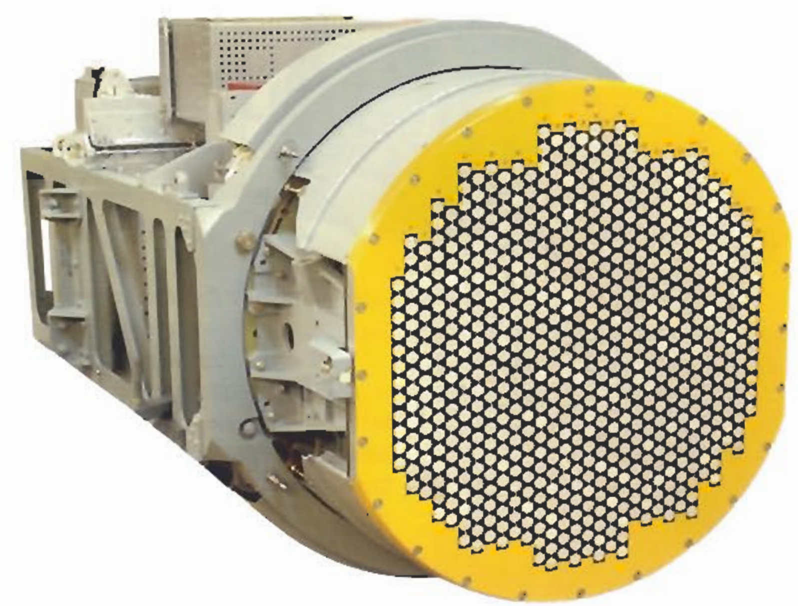
Zhuk-MFE airborne radar

Phazotron also offers the phased-array Zhuk-MSFE and Zhuk-MFE versions with electronic beam control. Phazotron's passive phased arrays with non-equidistant arrangement of radiating elements and optimal field aperture distribution ensure a beam deflection angle of +700 without parasitic sidelobes.

The experimental Zhuk-MFE is undergoing flight tests on a MiG-29. The Zhuk-MSFE, developed specially for the near-term naval fighter Su-27KUB and already installed on an experimental aircraft, has been in flight tests since 2003 and is also projected to be utterly effective.

All the abovementioned versions of the Zhuk radar family have passed many ground and flight tests. They are based on an open architecture, which means that any upgrade programs of tactical and naval aircraft in any country, if Zhuk is involved, will be fast and very cost-efficient.

Aware of its research and production capabilities and having secured a position in the top league of the industry, Phazotron finds it advisable to suggest the following forms of further military-technical cooperation with its Indian customers and prospects:



Zhuk-AE airborne radar

- upgrade of the operational Russian- and Indian-made aircraft with the Phazotron single-basis Generation 4+/4++ radars;
- adaptation, with subsequent supplies, of Phazotron Generation 4+/4++ radars for new aircraft expected to be developed in India in the near term;
- development and production of future, including Generation 5, radars for Indian customers (entire radar or certain parts of it, as the customer may suggest);

development and production of components for other radars of Indian design. ●

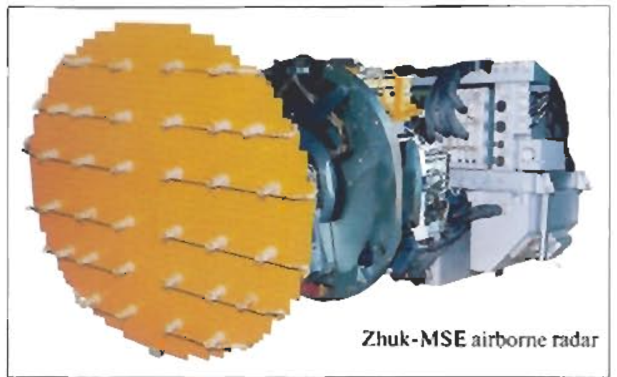
Phazotron radars as an upgrade opportunity for tactical aircraft

Igor Viktorov – deputy Director General, Phazotron NIIR Corporation
Vladimir Frantsev – chief designer, Phazotron NIIR Corporation

Much of today's aircraft fleet in many parts of the world is typically in service for 30 to 40 years. This is for a good reason: aircraft is an expensive thing, which means no air force can afford frequent replacements. However, all of them require high combat efficiency across the scope of missions through the entire lifecycle.

The solution is upgrade – not of the entire aircraft, because it would still be too expensive, but mainly of the avionics. It allows air forces, at reasonable costs, to step up their capabilities in response to changes in contemporary requirements.

The onboard radar, a key fire control system, is typically the first element on the upgrade waiting list. A replacement radar is


Zhuk-MSE airborne radar

more economically viable if it is modular, open-architecture, commonality-oriented, and cheap and easy to maintain.

Phazotron offers its Zhuk-MSE radar for the upgrade of Su-27 and Su-30 Flanker fleets.

This radar is based on the same main module as MiG-29SMT Fulcrum's Zhuk-ME. The key difference between the ME and MSE versions is the size of the slot array, 624 mm for the former and 960 mm for the latter. The Zhuk-ME has long completed its ground and flight test programs, is produced commercially and has earned a strong reputation in many countries as part of the MiG-29SMT.

The MSE derivative is installed on the Su-30MK3 which completed producer's flight test program, certified by Sukhoi Design Bureau CEO, on April 23, 2004, and is positioned as a multirole aircraft equally effective in air-to-air and air-to-surface combat and adaptable to versatile combat missions of today and possibly of tomorrow. Its radar efficiently supports all operational and near-term air-to-air and air-to-surface munitions used by the Flanker family in any tactical environment.

Flight tests have demonstrated the following features in its performance:

Air-to-air combat

The radar effectively scans the airspace, detects, identifies (incl. friend-or-foe) and tracks up to 10 aerial targets simultaneously, measuring their angular speed, speed relative to carrier, and distance relative to carrier in both front- and rear-looking hemispheres against the background of terrain as well as in free airspace. Of the 10 tracked targets, the radar selects four most dangerous and locks on them as the airspace is controlled in search for new targets.

At a long distance to a single target, the radar calculates missile launch zones and generates target designation commands (for the R-27R1 (ER1) missiles – radio correction and target illumination commands, for the RVV-AE active radar homer missiles – radio correction and target designation commands, for the R-27T1 (ET1) and R-73 thermal homer missiles – target designation commands only.

At a long distance to multiple targets (up to four targets can be engaged simultaneously), the radar calculates missile launch zones and generates radio correction and target designation commands for the RVV-AE missiles and target designation commands only for the R-73 missiles. In close combat, the radar locks on a visible target and interacts with the thermal direction finder through regular aircraft optics and pilot's helmet-mounted sight.

The radar can also be used for training. In this case, high-frequency radiation is turned off to extend lifecycle.

Air-to-surface combat

The radar provides real-time mapping of terrain in low (real beam), medium (Doppler), high (focused synthetic aperture) resolution or in the 'microplan' mode. In all three resolution modes, the map is stabilized relative to the aircraft. The mapped area is moved in range and cross-range automatically as the aircraft proceeds and can be moved manually if required. In the process, the radar detects, identifies, and locates stationary ground (on land) and surface radar-visible (at sea) objects, helps navigate the aircraft and generates target designation commands for the Kh-31A (AS-17 Krypton) missiles. The software-corrected tracking of up to two surface targets is supported.

The radar also supports the map freeze' mode in which transmitter operation is interrupted, the map is frozen in the screen, and a spot depicting the carrier aircraft is moved across it instead. The radar detects mobile ground (SNDTs mode) and sea surface (MP1/MP2 modes) targets.

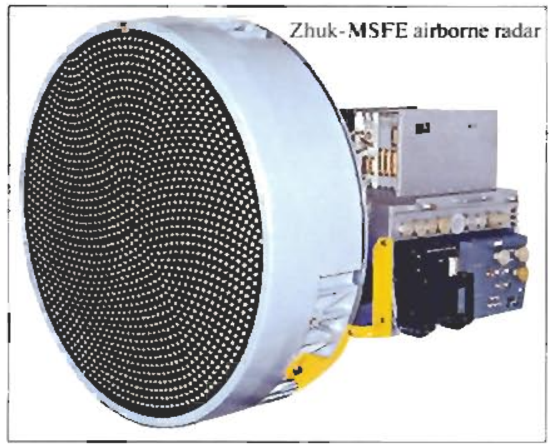
Together with modern smart missiles, the radar makes the Su-30MK3 part of a powerful multirole capability, key to achieve air superiority. In air-to-surface combat, the Zhuk-MSE outperforms international peers. With high reliability, relatively light weight for its class (280 kg) and low power consumption (12 kVA AC/1.5 kW DC), the radar is remarkably easy to maintain. Phazotron's trademark maintenance principle is that maintenance is to be done only in response to operability decline (i.e. no scheduled maintenance is required) and using only the built-in self-test capability whose job is to identify the faulty unit that has to be replaced for the system to operate normally.

The radar needs only pre-flight and pre-repeated-flight preparation, scheduled inspections, and repairs if required.

In flight, the radar operation is monitored continuously, with the parameters recorded onto a hard memory disc. Removable modules can be repaired at the airfield using special MRO control boards.

Phazotron consistently perfects its maintenance philosophy to help customers mitigate time and cost of maintenance for the radar and for the carrier aircraft. In addition to its open architecture and modular design advantages, the Zhuk-MSE is fully commercialised, which means that upgraded Su-27/30 Flanker fleets in any country are facing minimal expenses, and upgrade is going to take minimal time.

While the Zhuk-MSE is steadily strengthening its international record, Phazotron is nearing completion of an R&D effort on the next phased-array version Zhuk-MSFE. So far, flight tests have fully confirmed the effectiveness of the chosen aperture and key declared performances. In the future, the Flanker family will receive a new active phased array radar of the same family. So far, research in this department has been remarkably successful. ●


Zhuk-MSFE airborne radar

Phazotron radars for all-round-looking aircraft defense systems

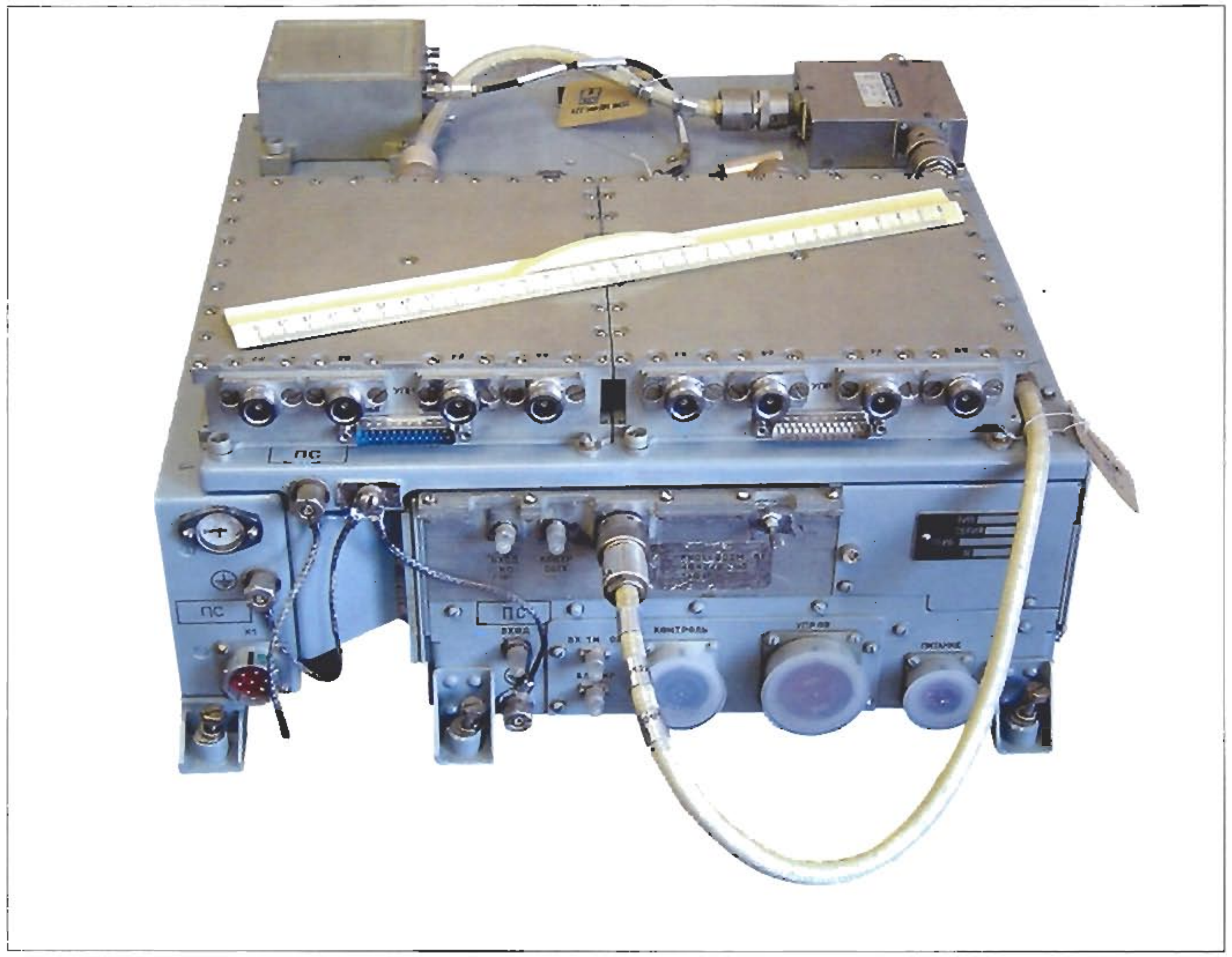
Pyotr Kolodin – deputy Director General, Phazotron NIIR Corporation, NII Rassvet Director
Sergei Zaikin – Chief Designer, NII Rassvet

The broader task of protecting an aircraft against surface-to-air or air-to-air missiles includes the detection of the incoming threat, the determination of its trajectory and level of danger, and counteraction.

Though various countermeasures systems are already on offer across the globe, the function of warning about the approaching missile threat, irrespective of the mode of flight, is performed by an integrated missile warning radar, which independently detects and selects the most dangerous incoming object, providing respective commands to the onboard (infrared or other) countermeasures system and sending a message to the flight control officer or other respective ground-based air traffic control authority.

Phazotron was the first Russian producer to develop a large-angle onboard radar with a full split-second missile detection and warning capability. It was integrated with an early Su-27 Flanker version in the late 1980s.

Since those times, Phazotron has chosen decimeter waves for radars of this purpose because such systems can – unlike those operating in



Transmission module

centimeter and millimeter waves – be equally effective when placed in various parts of the aircraft, including on top the main rotor (mirror-type parabolic phased-array aerials) or inside the blades in a rotary-wing machine, or flat aerials attached to the fuselage. The core of the radar is the same for all aircraft, only cases and

The Arbalet-D onboard aircraft radar

Purpose

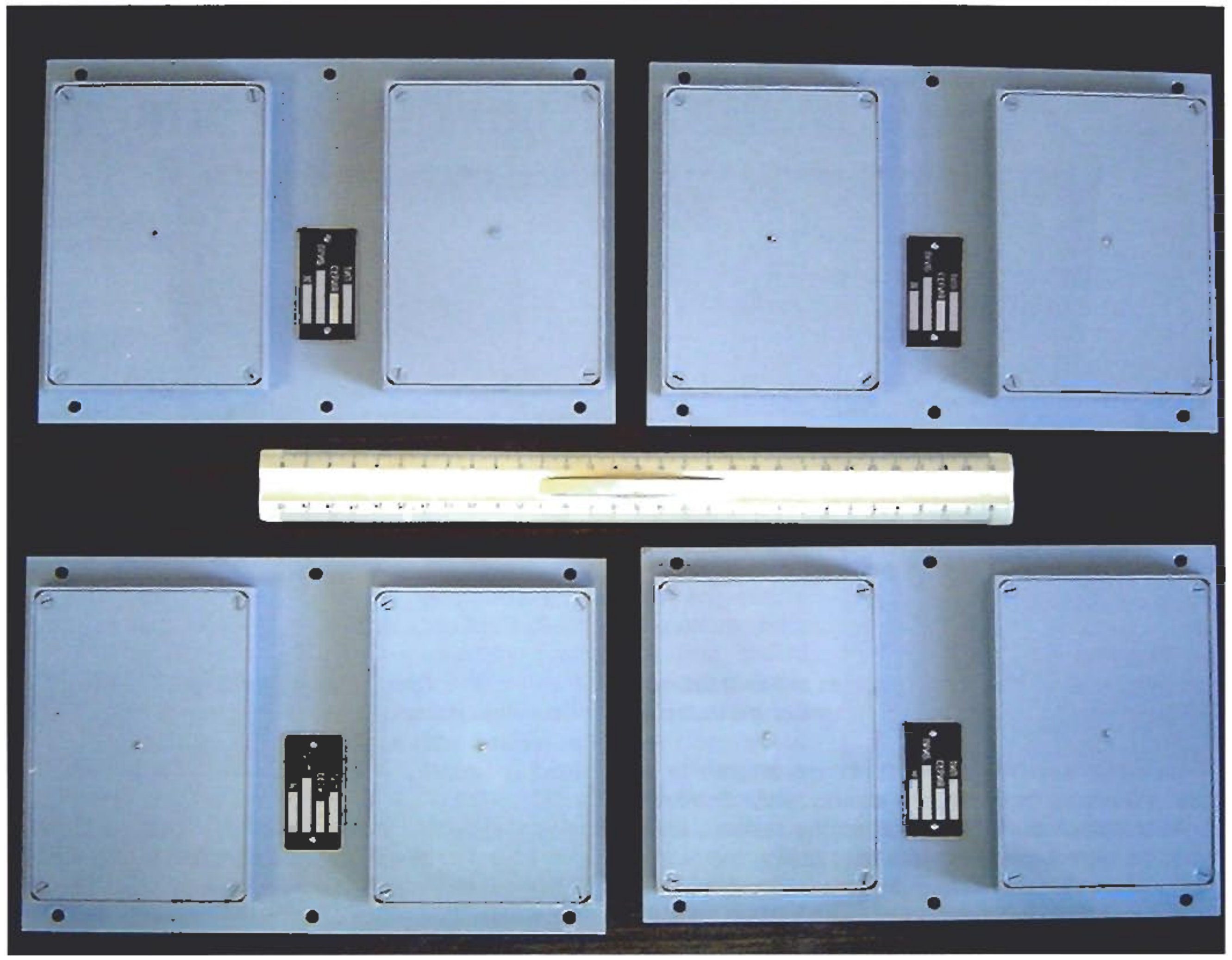
The Arbalet-D onboard aircraft radar is intended for use with attack and utility helicopters in solo or team military operations.

The all-weather day/night interference/jamming-resistant radar is installed as part of the avionics suite and fulfils the following functions:

– detects and measures incoming aerial objects, including Stinger-class surface-to-air missiles;

– provides the data to the flight computer to generate an appropriate defensive solution, to the crew, to ground-based flight control authorities, and to the flight recorder;

– provides data support to optical, optoelectronic, and other integrated threat warning systems.



Antenna modules

architecture differ. The system is also highly versatile in the configuration of the array because its transmitter has parallel transistors, which increases reliability.

In 20 years since the first rear-looking missile warning radar, the world has changed profoundly. The primary threat now comes from man-portable surface-to-air missile systems, or Manpads, many of which are believed to be in the possession of terrorist groups worldwide. In the past two years alone, western media have documented scores of cases of firing man-portable missiles at commercial airliners. In a world plagued by the growing number of local armed conflicts and increasing international terrorist activities, missile warning becomes equally important for civilian as well as military aircraft.

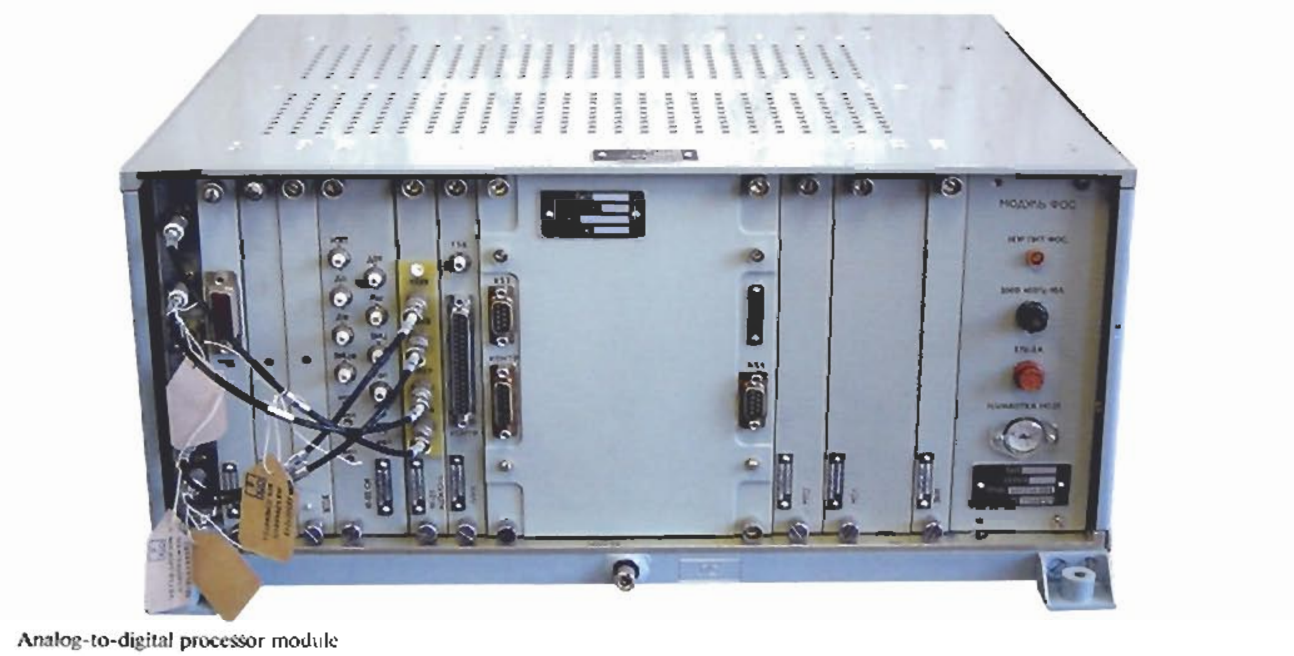
Phazotron analyzed the targets and challenges of aircraft missile defense and determined what a near-term onboard missile approach warning system (MAWS) should look like. The main requirements seem to be as follows:

- fast detection and short system response time;
- compatibility with operational and near-term avionics systems of all rotary- and fixed-wing aircraft;
- fast preparation for use and ease of operation;
- low cost and reliability;
- compactness.

The latter requirement was seen as especially important because the producer will never know which aircraft this system would be integrated with and whether the aircraft will have enough extra space and lifting capacity to accommodate it. Accordingly, a system easily integrated with as many types of aircraft as possible must be made up of interchangeable modules and be based on an open architecture. With the best places near the nose traditionally secured for forward-looking radars, additional all-round-looking radars have to be accommodated elsewhere. Interchangeable "click-in" modules make it possible to arrange the elements of such a system across the inner space even in well-packed aircraft.

The decimeter-wave Phazotron radar for helicopters is the Arbalet-D. Its main features are:

- reliable parallel-transistor transmitters;
- adaptive architecture for easy integration with various aircraft;
- highly integrated programmable microchips;
- solid-state compact frequency synthesizers;
- fast processing units.


Analog-to-digital processor module

Architecture

The system includes a set of modules and an installation package to connect the modules to one another and to aircraft systems.

The transmission/reception modules are designed to be placed inside, while the four antenna modules outside the aircraft.

All modules include built-in air cooling systems, which means the system does not require liquid cooling.

The system is powered by three-phase alternating (200 V 400 Hz, max 2kVA) and direct (27 V, max 0.5 kW) current.

The maximal weight is 40 kg, which makes this lightweight system compatible with operational as well as near-term rotary-wing aircraft.

Basic characteristics

Type	coherent-pulse radio detection and ranging system.
Waveband	L
Field of view/detection:	
azimuth	360°
elevation	– 30° to +30°
Azimuth scan speed	1,800°/sec
Minimal effective detection range	
Stinger-class missile	3.5 km
ground assault aircraft	10 km
Approach speed range	25 mps to 1,000 mps;
Maximal detection-to-tracking time	1 sec
Number of simultaneously tracked targets	4

Roll, pitch, heading, attack, and glide angles, and the ground speed components are taken from the onboard inertial navigation system; linear accelerations and angular speeds are taken from the respective sensors.

Operational characteristics

The initial readiness time, including the switch-on built-in self-test (also performed continuously during operation), is 4 min.

Reliability characteristics

TBF (on land + in flight)	500 hours
Turnaround time	5,000 hours
Service life	25 years

Maintenance characteristics

Type of maintenance	determined by operability
Number of maintenance levels	2
Maintenance means	
Level 1	built-in self-test
Level 2	MRO control panel

Level 1 'field-and-fast' maintenance uses the built-in self-test system, with the following performance:

Test credibility	0.95
Failure search depth	0.9
Test time	5 min
Repair time	25 min
Repair method	LRU replacement
Data recording target	aircraft test system

Phazotron has a capability to adapt the Arbalet-D to any type of light and heavy civilian and military aircraft.

Millimeter-wave radar homers for air-to-surface missiles

Vladimir Kurilkin – Chief Designer, Phazotron NIIR Corporation
Vladimir Merkulov – laboratory head, Phazotron NIIR Corporation

In the 1990s, multi-functional onboard aircraft radars received well-tested air-to-surface modes for high-resolution surface mapping and identification of small and mobile potential targets. However, the engagement of these targets was for a long time non-achievable because of the lack of truly all-weather day/night guided munitions.

To leap ahead of the trend, Phazotron set up a special unit to devise a compact coherent millimeter-wave homer for air-to-surface missiles, which would select small surface targets and guide the missile to them to a high precision. This was a tall order, given that the team faced very complicated and closely linked theoretical, procedural, and design issues, many of which had never been addressed before.

Lack of efficient cooperation with research, production subcontractors and educational centers was also a huge roadblock. In the course of the project, many problems were successfully solved because of close cooperation between our institute, the Zhukovsky Air Force Engineers Academy, and Central Institute 30 of the Russian Defense Ministry.

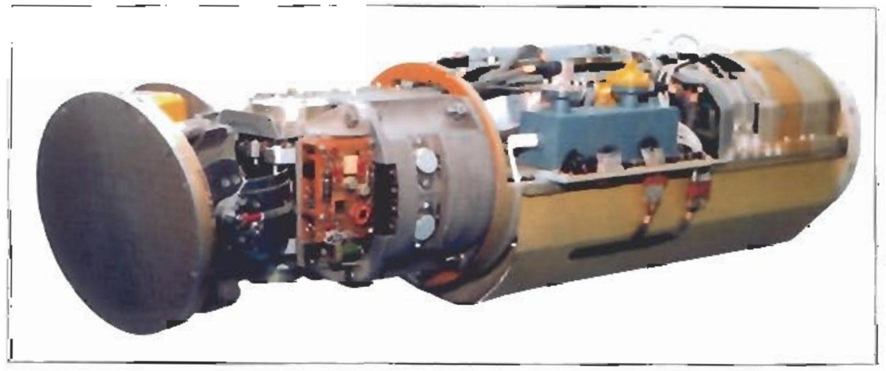
Theoretical issues included trajectory control algorithms to get aperture synthesis, necessary for extra-high cross range linear resolution and successful guidance to small surface targets. The irony is that aperture synthesis, crucial to high-resolution mapping, is effective only when the aircraft is moving at some angle to the target area, while effective engagement requires a direct hit. This means that a trajectory control algorithm should equally successfully serve two masters: provide high cross range resolution and low circular error. As the missile trajectory is curvilinear, cross range resolution is critical at the boosting stage (when the missile is necessarily moving at an angle to the aiming axis), while the hit probability depends upon high-precision guidance at the terminal stage. More importantly, this guidance system should consume as little power as possible because evasive maneuvers might cause a surge in overall power consumption. And all this should be done under crushing g-loads.

Clearly, traditional technology could not address these very contradictory challenges. A solution was found thanks to the statistical theory of optimal control. In all options that were on the table, we saw several similarities.

First is that prioritization is key to the understanding of such flight control. At the boosting stage (the distance to the target is long, the aiming axis angular speed is low), cross range resolution has the highest priority, but then gradually gives way to the guidance component as the missile closes in and the aiming axis angular speed increases. Our findings, protected by several patents, have ensured our priority in this area.

To make these algorithms work, the system needs to know the right relative bearing and distance to the target, which implies that the target has been reliably locked-on. It is also a tall order because the target's radar image is overshadowed by reflections from the surface. The solution was found in correlating extremities' – selecting several high-contrast small objects near the target as references. As soon as the problem of air-to-surface guidance with the aid of virtual high-contrast reference objects was first solved theoretically, and then confirmed practically, the truly all-weather day/night smart weapon capability became reality.

However, the broader problem was far from solved. The aircraft which launches the missile needs to be safe from enemy air defenses, which means firing off at a longer distance from the target. For such stand-off missiles, combined guidance systems – autonomous, without contact with the target, at the boosting stage and with synthetic aperture at the terminal stage – were devised, in which the 'go-it-alone' algorithms of the boosting stage could smoothly transfer control to the 'homing' ones at the terminal stage and the guidance system could estimate the relative bearing and distance to the target while making a synthetic aperture.



The task was split along the following lines:

- to devise compact low-noise stable millimeter-wave UHF devices;
- to develop digitally controlled heading-, pitch-, and roll-stabilizing servodrives;
- to make the array compatible with navigation sensors;
- to make synchronizers re-programmable, so that the whole system could adapt to the flight environment and be easy to upgrade.

One should remember that all these devices had to be very compact, light and very robust. Ultrahigh-precision millimeter waveguide and transceiver elements were made, thanks to which Phazotron, in close cooperation with MNII Agat (CEO Iosif Akopyan), made the Ka-band monopulse waveguide-slot array with high directivity and relatively silent sidelobes(-25 dB), which is critical in air-to-surface warfare.

Our coherent signal processing techniques also became a breakthrough into adjacent lines of scientific inquiry. One has resulted in new trajectory control algorithms with semi-active synthetic aperture, capable of selecting single aerial targets in a dense group, adapt to various modes of the onboard radar, and to various weapons. This was also key to the development of ultra-compact radars, including those for low-altitude flight control, and to a new generation of light but powerful millimeter-wave equipment (multiple-beam klystrons, travelling-wave tubes, synchronized magnetrons etc), including low-noise (no more than 4dB) UHF receivers, already produced commercially. We introduced an innovative waveguide-slot array technology and rendered crucial momentum to the development of Ka-band radio-transparent materials used in nacelles.

The work to produce an off-the-shelf all-weather day/night millimeter-wave homer is well on track. The first stage of ground tests has confirmed that we have been moving in the right direction; we are also very optimistic about other forthcoming tests.

What has been done is important not only for practical purposes – clearly, having air-to-air and air-to-surface missiles with all-weather day/night homing capability is a good thing – but also as one of the first insights ever into how things work above the well-studied radio frequency range. ●

Functionality and challenges of helicopter radars

Valery Ratner – Chief Designer, Phazotron NIIR Corporation

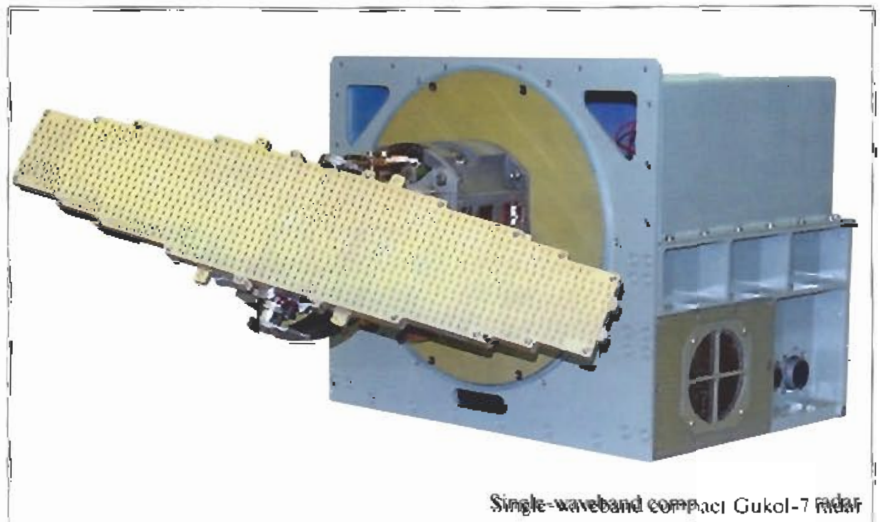
Phazotron NIIR has long been developing and producing commercial radars and fire control systems for tactical and multirole fighters. Phazotron's millimeter, centimeter, and decimeter radars, including dual-waveband (X/L) monopulsed phased-array radars and coherent synthetic aperture radars for rotary- as well as fixed-wing aircraft are in service with the Russian Air Force and over 30 other countries.

The corporate effort to develop radars equally matching the needs of different types of helicopters started years ago. Naturally, helicopter radars turned out to be very different from those installed in fixed-wing aircraft. Quality has become a major concern for Russian companies who were increasing their international operations and therefore had to maintain superior quality or face lost contracts and revenues as radars gained an increasing role in empowering helicopters as a formidable and highly mobile all-weather day/night weapon and vehicle.

A helicopter with a radar is far more formidable on the battlefield than a helicopter without one. A radar increases range and efficiency, adds a capability to navigate in adverse visibility conditions and find landing pads on difficult terrain, helps avoid collision in low-altitude flight, and facilitates blind landing.

In the military, a radar also raises the helicopter to a totally new level of combat power, reducing the time optical and electronic sights need to find the target, creating a genuine stand-off capability, and improving survivability by warning about approaching surface-to-air missiles and selecting the right time of use and amount of countermeasures.

Unlike radars for fixed-wing aircraft, there is, basically, little difference between radars for civilian and military helicopters. This is because civilian helicopters also perform versatile functions like border monitoring and detection of smugglers; monitoring of Arctic and other oil-producing areas; search for fish in high seas; determination of gravity of environmental disasters (oil spills, forests prone to fire etc.); and support of search-and-rescue and disaster relief operations in any outside conditions.



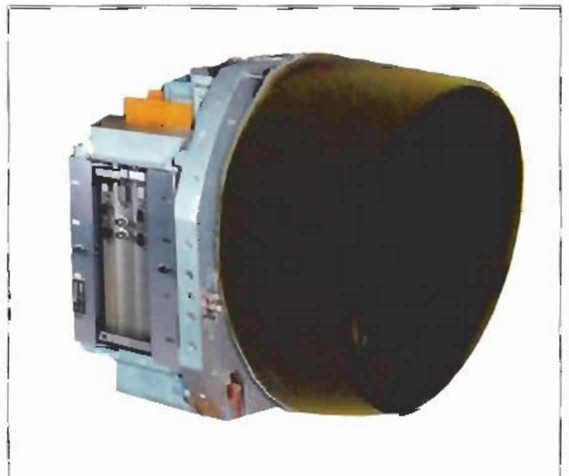
Single-waveband compact Gukol-7 radar

Features of helicopter operation and the scope of its missions called for new radars for rotary-wing vehicles but ruled out the option of developing a special type of radar for each type of helicopter. Special air-to-surface assault or search-and-rescue radars have been developed previously but have never been commercialized and remained on paper for decades.

Phazotron's family of helicopter radars is largely derived from the Kopyo radar that earned a strong international reputation on the back of Indian Air Force's major upgrade program for its fleet of MiG-21BIS UPG Fulcrum fighter jets. With its standardized functionalities and interfaces, modular design, open architecture, and a powerful computer, this radar was easy to develop into various other kinds of radars for helicopters of different use.

The family's most prominent common feature is a full all-weather capability because all radars can operate in several wavebands. An X/Ka/L combination makes ground objects radar-visible in any weather, raises the resolution and positioning accuracy, creates an all-round warning field, and increases the detection and lock-on range for aerial as well as ground targets.

In military applications, helicopters carrying advance parties or commando teams into action need to covertly approach the area, release the men, provide them effective fire support if necessary, collect them and return to base as silently as possible. Often such missions have to be carried out in poor visibility conditions when optical and electronic means fail by definition. This is where a cross-functional radar comes in.



Dual-waveband compact Gukol-10 radar

The three wavebands for aircraft radars are most effectively used in different missions:

Ka-band

The Ka-band is the best for fire support functions of attack helicopters as it well suits the purposes of supporting low-altitude flight, detecting meteorologically hazardous zones, and following the maneuvers of aerial targets like ground assault aircraft in the forward hemisphere. One prominent example is AH-64D Apache's Longbow Fire Control System.

L-band

The L-band (one example is Dassault's DAV) is the best solution for missile warning and helicopter defense all-round-looking radars tracing incoming missiles and enemy aircraft. Typically the antenna is mast-mounted, which eliminates ambiguity in the range and speed measurements and reduces the response time as the system detects an incoming threat. Alternatively, the all-round-looking capability may be built by placing several scanning antennas around the fuselage.

X-band

The X-band is typically reserved for long-range surveillance, reconnaissance, and weather monitoring. X-band systems transfer target designation information up the chain of command. The X-band is characteristic for many helicopter radars like the APS-143/147 or APS-784 and is the basic waveband for deck- or shore-based naval helicopters.

A radar working in two of the three or in all three of these bands should be able to perform all the above functions. Modular designs can be customized depending on the purpose and type of the carrier aircraft. If the system is based on the open architecture, it is good for the customer as various configurations are possible on the aircraft of the same design, as well as for the producer who benefits from cutting design, production, manufacturing, and logistics costs to come up with a new model – working, reliable and maintainable – as fast and cheap as possible.

Phazotron has developed a common platform for radars covering the full scope of missions modern helicopters are assigned. In military applications, a radar can increase combat effectiveness by up to 25% to 30%, while dramatically improving survivability under intensive enemy fire. Only the antennas and transmitters need to be adapted to customer's fleet and purpose: other analog parts are modular and differ only because of different operational wavebands. Open computing architecture and standard interfaces make a Phazotron radar flexible, upgradable and interconnectable with helicopter's original avionics.

All Phazotron's solutions have passed necessary tests and checks, which means that the Corporation can develop a fully customized radio detection and ranging solution for any type of helicopter within 18 to 24 months.

Functionality

Together with other onboard systems, the all-weather day/night interference/jamming-immune onboard radar's functionality includes:

- terrain scanning and mapping, changing the angle and scale of view if required;
- surrounding airspace scanning;
- detection, positioning, identification, and prioritization of ground, sea, and aerial objects;
- detection of ground obstacles and landscape mapping for low-altitude flights;
- data support for optical and electronic sights;
- detection of meteorologically hazardous areas;
- correction of the navigation system if necessary;
- control over guided and unguided weapons;
- friend-or-foe identification.

Kopyo-A aircraft radar: a comprehensive data management solution

Yury Bozin – deputy chief designer, Phazotron NIIR Corporation

Since 2002, Phazotron has been replacing Ka-28's (Helix) Osminog radar by Kopyo, a more powerful radar that can serve as a basis of a new data management system enhancing helicopter's combat performance.

Primarily designed for the Ka-28, this radar can also be installed on other manned fixed- and rotary-wing aircraft as well. It includes several fully detached units. In a helicopter, it is responsible for the navigator's data environment:

- detecting and classifying single surface or aerial objects or groups of objects;
- driving the helicopter or a group of helicopters along the path prescribed by the flight mission;
- scanning the tactical environment and making a tactical map;
- transmitting tactical data to upper-level stationary and mobile command-and-control centers;
- firing stand-off anti-ship missiles like the Kh-35 (SS-N-25 Switchblade) at surface targets;
- controlling sound buoy setting, searching for popped-up submarines, indicating preliminary enemy submarine data and supplying them to anti-submarine combat support systems;
- indicating "weapons-ready commands and recommended launch zones in anti-submarine carried out by a team of helicopters;
- driving the helicopter back to the host ship or point of departure.

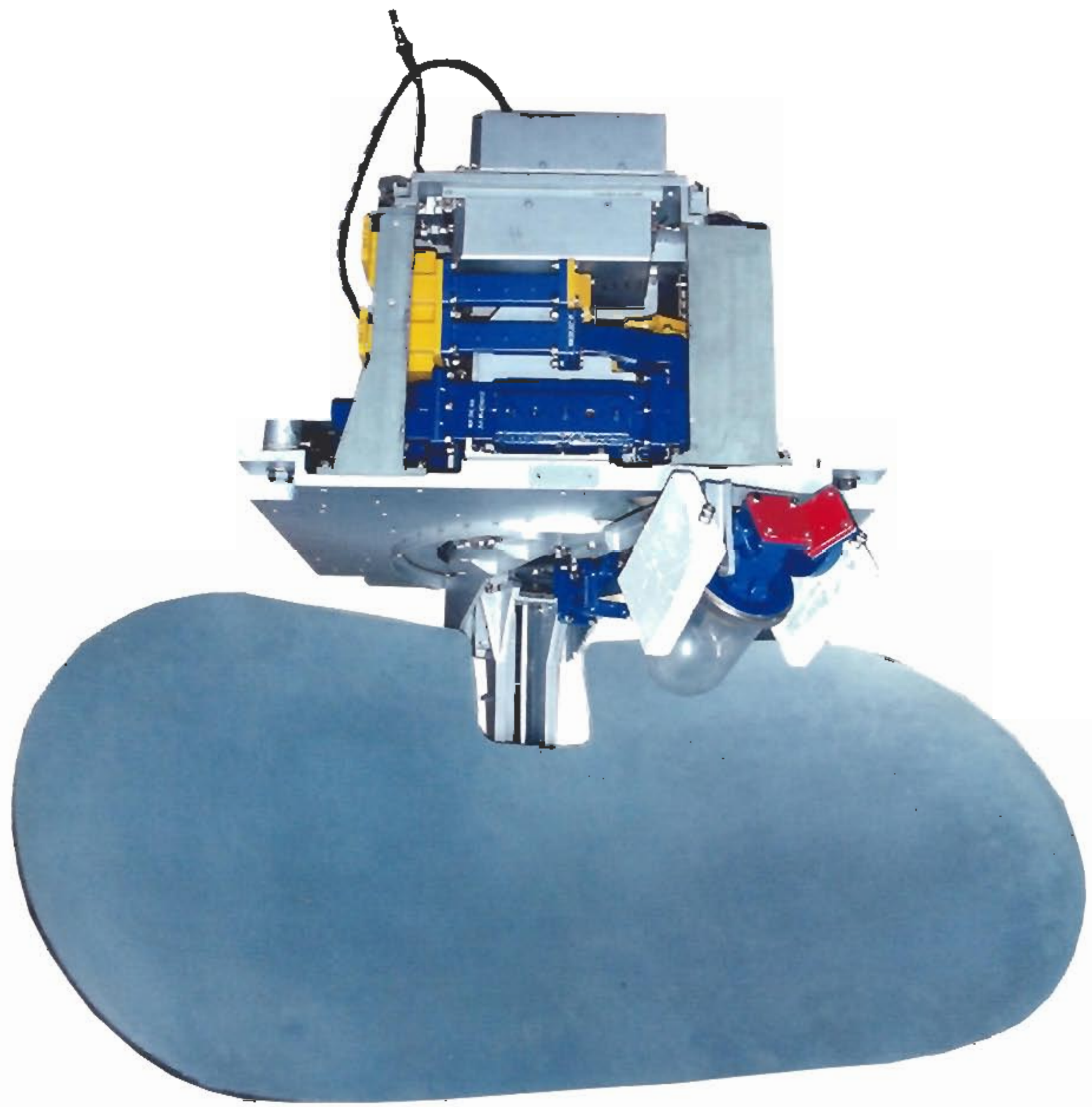
The data management system includes an onboard radar, an electronic signal monitoring station, a friend-or-foe transponder, and a radio modem. The system cooperates with the navigation, weapons control, and anti-submarine surveillance systems.

The operational modes are updated as the helicopter follows the flight mission and are affected by the helicopter airworthiness data. A crew training mode is also available. All modes can be selected by the navigator manually. The navigator also has soft keys which can be programmed to run this or that subsystem and re-programmed if necessary.

Radar functions include:

- all-round scanning of air and sea surface environment;
- directional scanning in a certain sector;
- manual or automatic (according to current altitude) switching of maximal scanning range between 260 km, 130 km, 65 km, and 10 km;
- built-in self-test;
- flight mission amendment;
- training mode;
- detection of surface and aerial objects and selection of mobile ones;
- coastline detection and high-resolution terrain mapping;
- radar mapping by the inverse-synthesized aperture method;
- track-while-scan of up to ten surface targets;
- detection and ranging of meteorologically hazardous areas (thunderstorms, downpours etc.).

The radar automatically classifies all detected objects, locks on and tracks the objects while scanning. Meteorologically hazardous areas are shown on the display automatically as



Kopyo-A airborne radar

Basic characteristics

Maximal effective range	250 km
Average scanning power	400 W
Waveband	450 MHz
Carrier band	X
Consumed electric power	5 kVA
Weight	130 kg
Cooling	air-cooled

Tactical performance

Effective detection range (sea conditions Force 3):

Target radar cross section, [m2]	Range, [km]
1	42
3	56
5	63
10	77
100	112
1000	168

Hi-res terrain mapping resolution	5 m x 5 m
Inverse-scanning aperture resolution	0.5 m x 0.5 m

In both inverse-scanning aperture and hi-res terrain mapping modes, the display shows a synthesized 5 km x 5 km map.

they emerge. The operator can manually control the scanning sector and range.

The operator can also use the control stick to select the tracked target or to switch on the inverse-synthesized aperture mode or high-resolution terrain mapping mode.

The color liquid-crystal display shows navigation, flight mission, battlefield data, and the radar and topographical maps. Importantly for team missions where it is of crucial importance to make full use of all system capabilities, any radar can also process information received from other helicopters in the team with adaptation to the real tactical environment.

In both inverse-scanning aperture and hi-res terrain mapping modes, the display shows a synthesized 5 km x 5 km map.

In effect, the Kopyo-A greatly increases the scope of radar use with Helix and other aircraft, providing what is in effect a comprehensive all-round 250-km air environment monitoring capability. ●

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