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Yanovsky, Felix; Samczynski, Piotr

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Untold Facts About the Early Radars in Ukraine and Poland

Felix Yanovsky
Department of Electronics
State University 'Kyiv Aviation Institute', Kyiv, Ukraine
and GRS Department, Delft University of Technology
Delft, The Netherlands
yanovsky@kai.edu.ua; F.Ianovskyi-3@tudelft.nl

Piotr Samczynski
Department of Electronics and Information Technology,
Institute of Electronic Systems
Warsaw University of Technology
Warszawa, Poland
piotr.samczynski@pw.edu.pl

***Abstract*—The evolution of radar technology in the early twentieth century is often narrated through the well-known contributions of Western scientists. Independent pioneering work in Eastern Europe—particularly in Ukraine and Poland—remains underappreciated. This paper considers the early radar experiments and innovations emerging contributed by Ukrainian institutions and experts. In addition, the paper highlights the important contributions of Polish scientists. Together, these untold facts underscore the collaborative and international roots of modern radar.**

Keywords—early radar technology, Ukrainian Contributions, Polish microwave engineering, radar history, radar pioneers

I. Introduction

The advent of radar technology in the 1930s was not only a milestone in military science and engineering but also a catalyst for broader technological innovation. While the narrative of radar's development often focuses on contributions from the United Kingdom and the United States, equally transformative work was underway in other countries as well. In the Eastern Europe, and particularly in Ukraine, early experiments and theoretical breakthroughs laid the groundwork for later operational radar systems. Ukrainian scientists — born, educated, and working in centers like Kharkiv and Kyiv — played a central role in advancing the field. Ukraine emerged as a vibrant center of scientific inquiry, where institutions such as Kharkiv State University (KhSU) and the Ukrainian Institute of Physics and Technology (UIPT) achieved essential advances in radio physics and electronics [1], [2]. Simultaneously, across the border, Polish research contributed significantly to the understanding of microwave generator theory. This paper aims to redress the balance by presenting these untold facts, thereby offering a broader perspective on the early history of radar, focusing on Ukrainian contributions and the parallel advances made by the Polish scientists [3] in microwave generation — provided essential theoretical insights into the key components in developing the emerging field of radar.

II. Historical and Political Background

As a result of WW I, several empires — which had once divided Ukrainian lands among themselves — began to collapse. Immediately following the victory of the Russian February Revolution in 1917 in Petrograd, the Ukrainian Revolution began. During this time, a national representative body—the Ukrainian Central Rada (UCR) — was established in Kyiv. After the Bolsheviks seized power in Petrograd, hopes for a democratic order in Russia evaporated, and the UCR proclaimed an independent Ukrainian People's Republic (UPR). Almost immediately, however, it faced Bolshevik aggression from Russia. Amid the heat of hostilities, the UPR signed the first international treaty in modern Ukrainian history in Brest. Diplomatic recognition and military assistance from the Central Powers bolstered the UPR and enabled it to reclaim territories occupied by the Bolsheviks. Nevertheless, the UCR had not created a strong enough army and faced significant organizational and political challenges.

In April 1918, a military coup occurred, resulting in Pavlo Skoropadskyi — a descendant of a Cossack hetman, who was proclaimed hetman of Ukraine and "anointed" by the church — coming to power. Hetman Pavlo Skoropadskyi took advantage of the brief period of peace to consolidate the foundations of Ukrainian statehood. During the Hetmanate, an effective administration was established that controlled vast Ukrainian territories, and negotiations were held regarding the incorporation of Crimea and Kuban into the Ukrainian State. At that time, the Ukrainian State was recognized by 30 countries. In that short period, a new university was opened and an Academy of Sciences was founded in Ukraine. An ambitious military reform was not completed due to unfavorable external and internal political circumstances. The achievements in state-building during the Hetmanate were later utilized by the re-established UPR, now headed by the Directorate—that is, a collegial authority.

The Directorate restored the republican system and democratic governance in Ukraine [4]. A Labor Congress convened by the Directorate provided a broad representative foundation for Ukrainian authority. A delegation of the UPR even took part in the Paris Peace Conference, where the fate of the participants of WW I was decided.

The collapse of the Austro-Hungarian Empire paved the way for the independence of its peoples. Galicia, centered in Lviv and once part of the Galician-Volhynian Principality—a state linked to Old Rus state with the centre in Kyiv — became the arena for a rivalry between Ukrainian and Polish national liberation movements. The rights to this region were simultaneously claimed by the Ukrainian National Council and the Polish Liquidation Commission. Ukrainians in Transcarpathia and Northern Bukovina gravitated toward their Galician brethren, though their lands were also subject to the ambitions of neighboring states.

In the contest for primacy in Lviv, the Ukrainians prevailed, swiftly and decisively establishing control over the region. The provisional fundamental law on the state autonomy of the Ukrainian lands of the former Austro-Hungarian monarchy introduced the name of a new state—the West Ukrainian People's Republic (WUPR). The Act of Union between the UPR and the WUPR attested to the Ukrainian people's desire for unity. However, the Galicians were unable to consolidate their success. After a month of fierce fighting, the Ukrainians were forced to abandon their capital, and a protracted Ukrainian–Polish front was formed. Initially, the battles were of a positional character, which allowed the WUPR to organize state affairs—implement reforms, and establish an effective government, administration, and military. The anticipated assistance from Kyiv — on which the state men of the WUPR had counted when signing the Act of Union on January 22, 1919 — failed to secure victory against Poland. Strengthened Polish troops,

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supported by the victorious Entente, occupied almost all of Eastern Galicia. In the end, the government and army of the WUPR were forced to cross the Zbruch River and join forces with the Directorate in Podillia.

Throughout this period, the UPR waged arduous battles for independence and territorial integrity. Together with the Galician Army, the UPR Army demonstrated heroism and refused to capitulate, even when only a few small detachments remained under the Ukrainian banner. The counteroffensives of March 1919 and the signing of the Warsaw Agreement laid the foundation for a long-lasting Ukrainian–Polish alliance and provided a tentative glimmer of hope for victory in the spring of 1920. A massive insurgent movement continued until November 1921; however, the forces were not equal.

In 1921, after several wars between Soviet Russia and the UPR, almost the entire territory of Ukraine fell under the control of the occupiers. The Treaty of Riga, signed in March of the same year between the Soviet governments of Russia and Ukraine and Poland, effectively buried the independent plans of the UPR and WUPR governments. Earlier, in 1918, Romania had occupied Bukovina; in 1919, Transcarpathia was ceded to Czechoslovakia; and in 1923, Eastern Galicia was annexed to Poland.

Despite the fact that all the lands of modern Ukraine came under the control of four different states, the unity of the Ukrainian nation was never in doubt. It was during the Ukrainian Revolution that Ukraine's independence was proclaimed, demonstrating the possibility of a civilized, democratic unification of territories into a single sovereign state. This marked a significant—and in many respects tragic—experience in the state and legal building of Ukraine.

Most of Ukraine eventually fell under Bolshevik control, led by Lenin. Yet the situation remained tense, as the authorities feared further resistance and uprisings. Therefore, it was decided to simulate independence—Ukraine would appear independent, but remain Soviet under the slogans "land to the peasants, factories to the workers." On December 30, 1922, in Moscow, the First Congress of Soviets took place, at which delegates from four socialist republics — the Russian Federative, Ukrainian, Belarusian, and Transcaucasian Federative Republics — approved the draft Declaration and Treaty on the formation of the Union of Soviet Socialist Republics. According to this treaty, the republics were independent and even had the right to withdraw from the Union, but in practice, all governance was carried out by the Communist Party with its center in Moscow. In the early years, national policies were favorable to the common populace of the republics: national schools operated in Ukraine, and the Ukrainian language, science, and culture flourished. Later, however, a policy of total Russification began. But that is another story.

The history of Poland is no less dramatic. After centuries of complex and brilliant past, in the end of 18^{th} century its entire territory was for a long time divided among three neighboring states, despite the desperate and heroic resistance of the Polish people. A large part of Poland including Warsaw, was also under the rule of the Russian Empire. World War I and the significant subsequent changes on the political map of Europe became the long-awaited moment for Polish leaders. About two million Polish soldiers fought on the fronts of World War I, supporting the armies of the Triple Entente, while the Polish political elite worked to persuade the Franco-Russian-British alliance to restore Poland's independence. Thanks to these efforts — and many favorable events, including the revolutions in Russia and Germany — Poland regained its independence on November 11, 1918.

III. Ukrainian Contributions to Early Radar Development

A. Institutional Background

In the context of the history of radar development, it is important to note that in the early decades of the twentieth century, Ukraine was an important scientific center. Kharkiv and Kyiv were major centers of industry, culture, and science, each with long-standing academic traditions. KhSU educated many distinguished scientists. Among them were mathematicians S. Bernshtein, M. Ostrogradsky, A. Lyapunov, and V. Steklov; biologist I. Mechnikov; and chemist N. Beketov. Esteemed figures such as A. Akhiyezer, L. Landau, I. Lifshits, K. Sinelnikov, and D. Mendeleev delivered lectures at KhSU. The university developed into a hub of scientific and technological progress. Following the coup d'état in October 1917 and then Bolsheviks' occupation in the civil war, Kharkiv was selected as the capital of Ukrainian Soviet Republic and held this status from 1919 to 1934. In 1921, Ukraine's first physics research department was founded at KhSU [5] under the direction of esteemed physicist Dmitry Rozhansky.

Kharkiv became synonymous with advanced research in radio physics. Subsequent development of KhSU into a hub for scientific inquiry laid the groundwork for a generation of researchers who would later propel radar technology forward. In 1928, on the initiative of Academician Ioffe, the UPTI was founded in Kharkiv. The establishment of UIPT, where mostly graduates of the KhSU worked, further strengthened the Kharkiv school of radio physicists by providing state-of-the-art laboratory facilities and fostering a collaborative environment that encouraged innovation despite challenging political conditions.

B. Key Figures and Their Contributions

Abram Ioffe was born in the town of Romny, located in the Poltava region in central Ukraine. He received his secondary education at a specialized school in Romny. Notably, his schoolmate and close friend was Stephen Timoshenko, widely regarded as a founding figure in modern engineering mechanics. Ioffe earned his PhD at the University of Munich, studying under W. K. Roentgen. In 1911, he measured the electron's charge, though his findings were published in 1913—shortly after the publication by Millikan, who is commonly credited as the first to do so. Ioffe excelled in building scientific institutions and fostering a productive research environment. In 1916, he launched a Physics Seminar for early-career researchers, which would later produce many of the leading figures in Soviet physics, including A. Alexandrov, P. Kapitsa, N. Semyonov, L. Artsimovich, I. Kikoin, Ya. Frenkel, I. Kurchatov, among others. After the 1917 October coup d'état, Ioffe remained active in shaping the scientific landscape under the new regime. He became a highly respected figure and a central influence in both physics and engineering. He was also a skilled and pragmatic figure within the political landscape, which allowed him to remain neutral for a long time and continue supporting science and scientists despite the complexities of Soviet life. Surprisingly, he only joined the Communist Party in 1942, during the war, at the age of 62. While Ioffe officially held the position of Vice-President of the Academy of Sciences (never its President), he was widely regarded as the leading academic authority — often referred to as the “Principal” Academician, the father of Soviet physics, or simply “Papa Ioffe.”

He founded and directed the Institute of Physics and Technology (IPT), later known as the Leningrad IPT (LIPT). A substantial number of research projects carried out at LIPT did not bear his name, despite his major involvement. Ioffe was known for his selflessness in science and often supported his students without seeking credit. He played a leading role in establishing institutes of physics and technology in Ukraine, including in Kharkiv and Dnipropetrovsk (now Dnipro). Though he could have led the Soviet atomic program, he declined Stalin’s offer, instead recommending one of his younger protégés. In the early 1950s, during the USSR’s anti-Semitic campaign under the banner of “combating cosmopolitanism,” Ioffe was removed from the very institute he had created. Still, he remained active: he founded a new Semiconductor Laboratory, and after Stalin’s death, he became director of the institute that grew out of this laboratory. Ioffe was always quick to engage with emerging ideas — radio-based aircraft detection was one such area. On February 7, 1934, he convened a meeting with his colleague Dmitry Rozhansky and other specialists. Following a constructive discussion, the Red Army’s Air Defense Department signed a contract on February 19, 1934, to study how electromagnetic waves reflect from various surfaces, to develop technologies for radio-based detection, and to conduct early experiments in locating aircraft. While Ioffe was not directly involved in designing radar systems, his influence was considerable.

Dmitry Rozhansky was born in Kyiv and attended the Kyiv High School, which was also the alma mater of renowned aircraft designer Igor Sikorsky. He graduated from St. Petersburg University and spent half a year working in Professor H. Simon’s laboratory in Göttingen, Germany. Then returned to Kharkiv in 1911 and worked in KhSU, became a professor at physics department more than 10 years. In that time, he created the physical foundations of high-frequency radio engineering, as evident in his seminal works such as Electric Rays [6] and Electric Oscillations and Waves [7].

In 1924 Rozhansky joined the the team of Leningrad Polytechnic Institute by Ioffe invitation. Here he became the head of the Department of Technical Electronics. Even after his departure from Kharkiv, Rozhansky maintained strong ties with his Kharkiv colleagues and students, visiting the city twice a year [8]. In 1925, he returned to Ukraine to serve as Full Professor and the Physics Department Head at KhSU. Rozhansky was among the first to recognize the potential of high-frequency radio engineering and initiated research into electromagnetic oscillations, which ultimately laid the foundation for the entire Kharkiv radiophysics community. His vision and leadership not only advanced theoretical understanding but also spurred practical experiments that would later be instrumental in radar development. Here in KhSU one of his talented students was Yu. Kobzarev who assisted Rozhansky during his Kharkiv experiments on receiving signals. Later Rozhansky invited Kobzarev to work together in Leningrad.

Nice to note Rozhansky was a man of integrity and strong moral principles, who never acted against his conscience and was unafraid to voice his views. This was particularly difficult during a time in the USSR marked by growing suspicion, widespread surveillance, and the looming wave of mass repression in the 1930s. Across the huge country, the campaign against "enemies" was intensifying. In Leningrad, a group labeled as "saboteurs" was accused of a mass poisoning incident at a factory, resulting in the execution of 40 people without trial. In institutions nationwide, meetings were held where attendees typically voted unanimously to endorse such executions. At one such gathering on September 25, 1930, Rozhansky stood up and declared his opposition to executions, particularly those carried out without judicial process [9]. This courageous declaration probably resulted in his arrest on the night of October 4–5, 1930. Abram Ioffe promptly took action, appealing for Rozhansky’s release, but it took nine months before he was freed. Fortunately, after his imprisonment, Rozhansky was able to resume his scientific and teaching work for several more years.

In the summer of 1935, a specialized laboratory focused on the radio detection of aircraft was established at LPTI, led by D. Rozhansky. Within this lab, the pulsed radar technique for aircraft detection was developed. By the end of that year, an experimental setup had been constructed, serving as a prototype for what would later become the "Redut" pulse radar. After Rozhansky’s death in 1936 at the age of 48, his student, Yuri Kobzarev, took over leadership of the laboratory and successfully completed the development of the Soviet Union’s first long-range pulse radar system for detecting aircraft.

Rozhansky had a remarkable ability to inspire young talent and supported many individuals who later gained prominence. It is thus not surprising that two of his former students—Abram Slutskin in Kharkiv and Yuri Kobzarev in Leningrad, both alumni of Kharkiv University—later headed key initiatives in the creation of the first pulsed radar systems.

Abram Slutskin. Between 1925 and 1950, A. Slutskin stood out as the most influential figure in Ukrainian radio physics and electronics. He played a key role in the development of modern microwave science. Slutskin enrolled in the Physics and Mathematics Faculty of the KhSU in 1910, around the time Rozhansky took charge of the department. Rozhansky initiated a physics seminar that actively involved students, an experience that, according to Slutskin, sparked his lifelong passion for electronics. After graduating in 1916, Slutskin stayed on at the university as an assistant in the Department of Physics. Since 1928 he served as a professor. He also spent three weeks working in Barkhausen’s laboratory in Göttingen, Germany. A major milestone in the evolution of Kharkiv's radio physics community came in 1928 with the establishment of a new research and development institution, known as the UIPT. The formation of this institute was largely driven by A. Ioffe’s efforts. A. Slutskin, along with his colleague D. Shteinberg (1874–1934), joined the UIPT team, while both continued holding their university positions.

Slutskin was a physicist with a strong passion for engineering, particularly in the emerging field of microwave electronics, where he accurately anticipated key developments. In the early 1920s, he explored the behavior of vacuum tubes in magnetic fields and achieved oscillations similar to those produced by magnetrons. By 1924, Slutskin succeeded in generating L-band oscillations and continued striving to reach even higher frequencies. Later, the development of the 3-D pulse radar operating in the L-band at UIPT was largely driven by Slutskin’s insight and initiative, as there was no strong technical rationale at the time for choosing that specific frequency range or using the pulsed approach. His dedication to advancing research in higher frequency bands later became a defining principle for his students and followers.

Alexander Usikov (1904–1995) was one of Slutskin's students and close collaborators. Born in the Sumy region, he graduated from KhSU. In 1930, the Laboratory of Electromagnetic Oscillations (LEMO) was established as part of UIPT, with A. Slutskin naturally appointed as its head. Usikov worked within this laboratory and later played a key role in founding the Institute of Radio Physics and Electronics (IRE) in Kharkiv in 1955, becoming its first director. The IRE specialized in advancing research in the millimeter and submillimeter wavelength ranges.

Semen Braude (1911 - 2003) was another young follower of Slutskin who worked within the dynamic environment at UIPT to refine key radar components. He was born in Poltava and graduated from KhSU in 1932. Later he became one of the pioneers of radio astronomy. Under his leadership, the first radio astronomy observatory in Ukraine was organized and original radio telescopes with electrical beam control were developed. We can't mention here all notable contributors, whose collaborative efforts led to experimental setups like the Zenit radar prototype, which demonstrated the feasibility of using high-power microwave pulses for target detection [2]. These technical innovations not only advanced military capabilities during a period of intense global war but also laid the groundwork for future civilian radar applications.

C. *Technological Innovations*

Magnetrons. The collective efforts of the Ukrainian research community resulted in several key breakthroughs. One significant achievement was the development of relatively powerful high-frequency generators, particularly magnetrons, which later became key components of a radar system. Exactly UIPT was among first institutions to successfully advance effective magnetron technology. But Slutskin had initiated the work in this area even earlier, in 1924. Following his success in producing L-band oscillations with magnetron-type generators — then the highest frequency achieved — he dedicated himself to pushing the boundaries toward even shorter wavelengths. He proposed the split-anode magnetron which was then a completely new method of producing oscillations. He studied physical principles and the conditions necessary for the split magnetron excitation and formulated a theory for the dynatron mode of a magnetron oscillator. A. Slutskin and D. Shteinberg [10] researched the behavior of electron tubes under the influence of external fields. Using a three-electrode tube, they managed to generate electromagnetic oscillations in the frequency band of 100 to 750 MHz [11]. Subsequently, they explored how factors such as tube geometry, operating conditions, and magnetic field strength affected performance [12]. At their request, the industry produced diodes featuring anodes made from non-magnetic materials like tantalum [10], [13]. By late 1925, their efforts resulted in the generation of 7.3 cm wavelength oscillations, as highlighted in a commemorative article on Slutskin [14], written by I. Truten (1909–1990), former student of Slutskin. Undoubtedly, A. Slutskin and D. Shteinberg deserve recognition alongside their Western contemporaries as pioneers in the development of magnetron oscillation technology.

Radio detection of aircraft. Ukrainian scientists systematically contributed to rapid technological change leading to creation of radar. It is worth to note that the results on magnetron generators, got by A. Slutskin and his team, were used in the Central Radio Laboratory [15] when creating facilities for radio-detection of airplane in 1934. Since September 1934 UPTI started to supply the magnetrons of different power and frequency to the design bureau of the Red Army Air Defense. By the end of 1936 [10], LEMO-UIPT had carried out wide range fundamental research on the magnetron method, and had a complete set of L-band magnetrons, both for CW and pulsed operation.

Pulse Radar Systems. Research in this field continued at the LEMO within UIPT, with A. Slutskin serving as its head from 1930 onward. By late 1936, Slutskin had proposed and planned an ambitious project to create the first pulsed radar system capable of determining all three spatial coordinates of a target, while existing experimental prototypes at the time could identify only two.

Zenit Radar. In March 1937 the UIPT started the project on L-band pulse radar for anti-aircraft artillery [16]. It had to operate in 460 to 500 MHz frequencies. By July 1937, a draft design was completed for a short-range air target radar system. It featured a specially developed magnetron capable of delivering 1 kW of power at a wavelength of 68 cm [17]. Codenamed "Zenit," the project was carried out under Slutskin's leadership by the team at LEMO. In mid-1938, the first field test of the Zenit prototype was conducted by attempting to detect a small aircraft. The prototype utilized a dual-antenna configuration: the transmitting and receiving reflector antennas were spaced about 50 meters apart to minimize interference from the powerful transmitter pulses. Both reflectors scanned synchronously in horizontal plane (360°) and vertical plane (90°), maintaining consistent alignment of their beam directions [18]. The transmitter was placed behind its parabolic reflector in a sealed metal housing, with a two-wire line coupled to the magnetron circuit, terminating in a half-wave dipole positioned at the focus of a reflector. The receiver had a similar design, with its electronics also enclosed in a sealed case. Synchronization of the reflectors' movement was achieved using selsyn motors. The initial tests provided valuable insights into improvements needed for the Zenit system. Encouraged by the promising results, efforts then focused on increasing the transmitted power and enhancing system reliability. The upgraded radar prototype operated with a 64 cm wavelength, delivered pulses of 10–12 kW, and had a pulse width 10 to 20 μs [17].

Shortly after, WWII broke out, followed within weeks by Soviet military campaigns in Poland, the Baltic States, and Finland. In 1940, a modified version of the Zenit radar was submitted for official testing. Final evaluations confirmed the system's capability to determine an aircraft's three-dimensional position across a range of altitudes. Reliable detection and 3D target positioning were achieved at distances from 6 to 25 km for altitudes between 4000 and 7000 meters; beyond 25 km, detection became less reliable. Comparisons between the radar-determined altitudes and barometric altimeter readings showed an average error margin of 5.2% to 8.9%. Some preliminary data on target resolution were also obtained [19]. Overall, the Zenit system met key performance expectations and generated significant engineering interest, particularly due to its ability to simultaneously determine range, azimuth, and elevation — something neither Britain's Chain Home nor Germany's Freya radars could accomplish at that time. Some drawbacks were also pointed.

Rubin Radar. The results of new R&D projects along with the experience gained during Zenit-radar design, development and testing allowed LEMO to move forward the work on the design of new Rubin radar in 1941. This new system aimed to achieve a greater target detection range and higher accuracy in determining target positions. Of particular significance was the innovation of using a single antenna for both transmission and reception. However, the rapid advance of the front lines in World War II forced LEMO, part of UIPT, to halt all work by July 1941. The team had to dismantle and pack their equipment for relocation to Bukhara, where the development of Rubin was ultimately completed.

The Rubin radar's antenna was designed as a 3-meter diameter paraboloid of revolution, with both the transmitter and receiver dipoles positioned at its focal point. To handle the significant wind load on such a large reflector, the dish was made collapsible, consisting of six detachable grid segments constructed from 2-mm diameter wire. One of the major technical challenges — operating a pulsed radar with a shared antenna while protecting the sensitive receiver from the powerful transmitted pulses—was ingeniously solved by I. Truten through the use of a gas discharger. The entire Rubin system was mounted on two trucks: one carried the power supply equipment, and the other housed the electronics. Testing took place in Moscow in 1943, and by early 1944 the radar was deployed to Murmansk, a polar port and naval base. There, Rubin demonstrated its capabilities by successfully detecting aircraft over the sea at ranges up to 60 km, even when planes were flying at extremely low altitudes of 30 to 50 meters. The system achieved an average range error of up to 120 meters, and an azimuth and elevation accuracy of about 0.8°. Measurements of angular coordinates never took more than 7 seconds. Despite its impressive performance and clear potential, the reasons why Rubin was never mass-produced remain a mystery.

D. IEEE Milestone

IEEE Milestones recognize the technological innovation and excellence for the benefit of humanity found in unique products, etc. Milestone "Zenit Parabolic Reflector L-band Pulsed Radar, 1938" was dedicated 2017/05/31 with the following citation [20]: "The 1938 Zenit radar test at the LEMO of the UIPT was a major advance in the development of radar. Designed by Abram Slutskin, Alexander Usikov, and Semion Braude, microwave scientists and magnetron pioneers, Zenit established the practicality of combining the pulsed method and a shorter wave band for determining precisely all three coordinates of airborne targets." The bronze IEEE Milestone plaque was presented to the IEEE Ukraine Section in 2017. In Fig. 1 the Director of the IEEE Region 8, Costas Stasopoulos (left), greets Prof. Alexander Nosich, the principal author of the application for this Milestone; on the right, the then Chairman of the IEEE Ukraine Section, Prof. Felix Yanovsky, one of the authors of this paper, stands. Out of almost 200 IEEE Milestones worldwide, only six have been granted to the developments of radar technologies, and one of them is located in Ukraine. This was a huge achievement, and, today, this is a great honor [21].

E. Post-war achievements

MTI. After World War II, in 1946, the Artillery Radio-Technical Academy (ARTA) was founded in Kharkiv. By that time, the principle of MTI using a delay line canceler was already established. In the late 1940s, Yakov Shirman, then a young instructor at ARTA, introduced a new concept: the multiple delay line canceler. This innovation greatly enhanced the effectiveness of MTI systems.

Fig. 1. IEEE Milestone Award Ceremony. From left to right: Kostas Stasopoulos, Alexander Nosich, Felix Yanovsky.

Shirman's invention was quickly adopted, first in the P-12 radar and later in the S-75 anti-missile radar system, as well as in many other radar technologies.

Pulse Compression. Ya. Shirman first introduced the concept of single-channel matched filtering for chaotic phase-shift keyed signals in 1955 [22], and later extended it to deterministic LFM sounding signals; that was patented in July 1956 [23]. The compression filter was constructed as a tapped-delay line, featuring either continuous or discrete taps with capacitive, inductive, or conductive coupling to the delay line. In 1956, the principle of LFM pulse compression was experimentally verified using a matched filter built around a spiral delay line.

The development of wideband pulse compression using matched filters stands as one of the most important advancements in radar theory and technology after World War II. This breakthrough was achieved in Ukraine independently at nearly the same time as similar work in the United States (by Charles Cook, 1955, published in 1968) [24]. Notably, Shirman's method was far more sophisticated and efficient than a bit earlier American approach.

Superwideband radar. Increasing the bandwidth of the radar sounding signal by as much as 100 times relative to systems available at the time led to major improvements in both range resolution and the precision of range measurements through matched signal processing. The first large-scale natural experiments using a superwideband LFM-pulse radar for aircraft surveillance were conducted between 1962 and 1964, utilizing the S-band PRV-10 radar [16], [25]. A groundbreaking compression filter for 2-microsecond LFM pulses with a 72 MHz bandwidth—based on coaxial cable—was developed by V.B. Almazov and D.A. Tsursky, who were then students under Professor Shirman. Tests with this radar achieved aircraft detection at distances up to 110 km, and real range resolution in the automatic lock-in mode was 4.5 to 3.0 meters at a range of 65 km. This performance allowed not only detection but even resolution of structural elements of airborne targets and enabled observation of their range profiles. To acknowledge his groundbreaking contributions, the IEEE Aerospace and Electronic Systems Society presented Yakov D. Shirman with the Pioneer Award, citing: "For the independent discovery of matched filtering, adaptive filtering, and high-resolution pulse compression for an entire generation of Russian and Ukrainian radars." He received the award during the International Radar Conference held in

Bordeaux, France, in October 2009. Sadly, Yakov Shirman passed away six months later, at the age of 90.

IV. Polish Pioneering Work

While Ukrainian scientists were forging the path in radar and microwave technologies, parallel work was taking place in Poland [3]. The Polish history related with radar starts in the 1920s, when one of the founders of Polish radiolocation, Professor **Janusz Groszkowski** from the Warsaw University of Technology, started his research in radio-communications technology. Professor Groszkowski published a revolutionary discussion in Polish in 1925 on "Cathode Waves and Their Use in Radiotelegraphy", which has since been translated into many languages; the first French translation was published in Paris in 1927. In the 1930s, he continued his research in this area, and in 1935 he established the State Telecommunications Institute in Poland, now known as PIT (PIT-RADWAR). Since then, tremendous progress in Poland in the development of applied technology in radio-communications has been observed. Many intentioned technologies invented by Professor Groszkowski were later applied in radars, the main two being the first oxide-coated cathode (1937) applied in magnetron [26] and the first metal magnetron with inner resonant circuits and an oxide cathode [27] (1939). Groszkowski's works played a complementary role to the developments in Ukraine. His pioneering studies not only advanced the theoretical underpinnings of microwave engineering but also influenced practical designs of radar components. The integration of his ideas helped bridge the gap between pure theoretical research and applied engineering solutions in radar technology. His legacy remains a testament to the international and collaborative spirit that underpinned the early innovations in this field. His early work created a solid foundation on which a powerful Polish radar science and industry grew after the WWII.

V. Conclusion

The early development of radar was not the sole province of Western nations; it was a global effort in which Ukrainian and Polish scientists made seminal contributions. In Ukraine, the dynamic research environment fostered by institutions such as KhSU and UIPT enabled breakthroughs in both continuous-wave and pulsed radar technologies. Key figures like Dmitry Rozhansky, Abram Slutskin, Alexander Usikov, and Semen Braude not only pioneered new techniques but also built a community of researchers who would carry forward their legacy. Equally important, the work of Polish scientist Prof. Janusz Groszkowski in the realm of microwave generator theory provided essential theoretical and practical insights that enriched the broader radar development narrative. Together, these untold facts remind us that the technological leaps of the 20th century were achieved through a rich tapestry of contributions from across Eastern Europe. Recognizing these efforts offers a more complete understanding of the evolution of radar and inspires further research into the collaborative nature of scientific progress.

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