Dramatic History and Impact of Decimeter-Wave Radar “Zenit” Developed in Kharkiv in the 1930s

Alexander I. Nosich
Laboratory of Micro and Nano Optics, Institute of Radio-Physics and Electronics NASU, Kharkiv 61085, Ukraine
anosich@yahoo.com

Abstract— **A major advance in the development of radar in the USSR occurred at the Ukrainian Institute of Physics and Technology (UIPT) in Kharkiv in October 1938, when gun-aiming radar Zenit was tested. Designed by Abram Slutskin, Alexander Usikov and Semion Braude, microwave scientists and magnetron pioneers, it established the practicality of the combination of pulsed method and a shorter wave band in the precise determination of all three coordinates of airborne targets. Finally a victim of inner feud around radar research in the USSR, this radar remained unknown until the late 1970s to wide public beyond of the microwave, electronics and radar community in Ukraine. Its history is closely tied to the invention of high-power decimeter-wave split-anode magnetrons in Kharkiv in the 1920-1930s. Another crucial point was discovery of the pulsed operation regime of such sources. Still the obstacles to be overcome on the way to working radar were formidable. Remarkably, the whole USSR research community was considering both the pulse method and the shorter waves as a dead-end. The working conditions were dramatic. In 1932-1933, the scientists had to close their eyes on the genocidal famine, which was devastating Ukrainian countryside by the orders from Moscow. Shortly after they had to learn how to navigate their lives and work between the deadly Orwellian torrents of the early USSR that culminated in the Great Terror of 1937-1938. Still, although Zenit has forever remained only a brilliant piece of engineering works, its role in the development of national Ukrainian microwave, antenna, radar and remote sensing community is outstanding. In 2015, it was awarded the status of IEEE Milestone.**

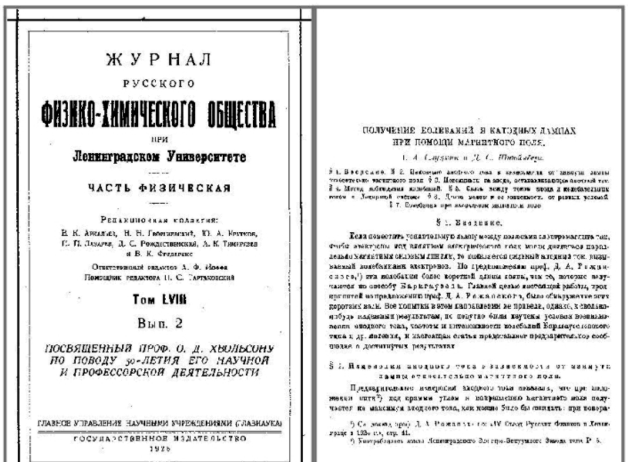
Keywords-early radar; Slutskin; Ukraine

I. Origins and Dates

The designing and testing of gun-aiming radar Zenit was performed in Kharkiv in 1935-1940 [1-7]. It was developed by a group of talented microwave and radar scientists headed by Prof. Abram Slutskin (1891-1950, Fig. 1), formerly a student of D. Rozhansky, himself a radar pioneer by 1934, who worked in Kharkiv in the 1910s. Slutskin was inventor of original L-band split-anode magnetron first reported by him as early as 1926 (Fig.2). Together with his team members and former students A. Usikov and S. Braude, he discovered, in the early 1930s, the regime of the pulsed operation of their magnetron.

The design of Zenit first came to the mind of Slutskin in 1935, was officially started in March 1937, and lasted, with breaks, till the end of 1940 when the project was finally closed.

Fig. 1 Professor Abram Slutskin in 1950.



ЖУРНАЛ
РУССКОГО
ФИЗИКО-ХИМИЧЕСКОГО ОБЩЕСТВА
ПРИ
Ленинградском Университете
ЧАСТЬ ФИЗИЧЕСКАЯ
Редакционная коллегия:
Том LVIII
Вып. 2
ПОСВЯЩЕННЫЙ ПРОФ. О. Д. ХВОЛЬСОНУ ПО ПОВОДУ 50-ЛЕТИЯ ЕГО НАУЧНОЙ И ПРОФЕССОРСКОЙ ДЕЯТЕЛЬНОСТИ
ГЛАВНОЕ УПРАВЛЕНИЕ НАУЧНЫМИ УЧРЕЖДЕНИЯМИ (ГЛАВНАУКА)
ГОСУДАРСТВЕННОЕ ИЗДАТЕЛЬСТВО
1926

ПОЛУЧЕНИЕ КОЛЕБАНИЙ В КАТОДНЫХ ЛАМПАХ ПРИ ПОМОЩИ МАГНИТНОГО ПОЛЯ.

§ 1. Введение.

Fig. 2. Title page of an 1926 issue of the Journal of Russian Physico-Chemical Society and the first page of article “Obtaining the oscillations from cathode tubes with the aid of magnetic field” by A.A. Slutskin and D.M. Shteinberg.

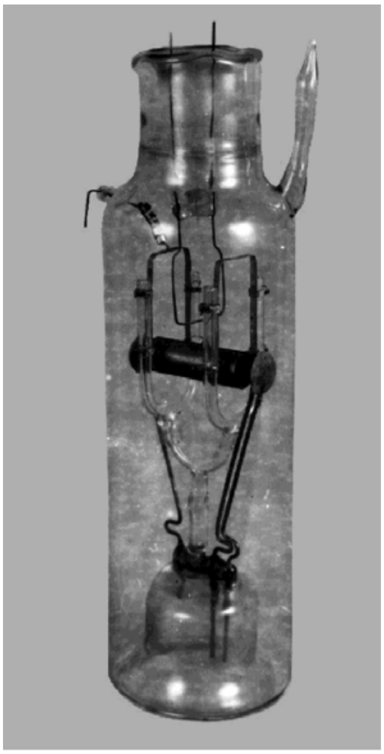


Fig. 3. Non-cooled 60-kW magnetron for 60 cm wavelength

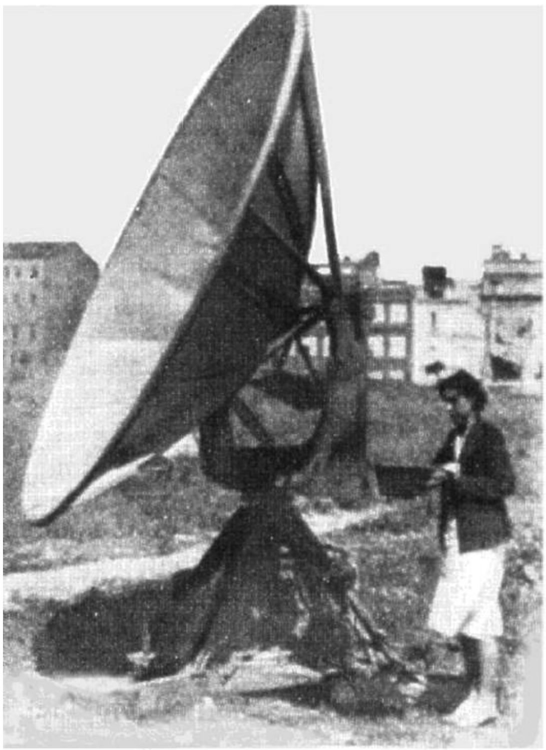


Fig. 4. Paraboloidal antenna and circuitry of the receiver unit of Zenit.

By the end of 1936, Slutskin's Laboratory of Electromagnetic Oscillations (LEMO) at UIPT had carried out a wide-range fundamental research on the magnetron generation method and had a complete set of the 60-cm devices both for CW and pulsed operation with the output power around 3 kW. This was not yet a cavity magnetron and therefore its operation was not very stable. Still it gave a solid ground for launching a complex work on developing the pulsed "radio-searchlight", as it was initially called by Slutskin. By that moment, several laboratories in the USSR were fiercely competing for the design of radar. However, only LEMO happened to possess two crucial ingredients: high-power source of shorter waves and trust to the pulse method. The pulsed mode of operation of magnetron seems to be the exclusive know-how of LEMO by 1936, without any close competitors in the USSR or elsewhere.

Young postdoctoral researchers Usikov and Braude were responsible for the transmitter and receiver circuitry of two-antenna Zenit, respectively. On October 14, 1938, according to Braude [4], the first successful field test of Zenit was performed in Kharkiv, demonstrating the ability to accurately determine all three coordinates of a flying airplane [1,2,5,8].

In fact, Zenit had good chances to serve, after upgrading planned for 1941, as a principal USSR fighter-guidance and gun-aiming radar system. This is proved by the records of the official government commission that tested Zenit in September 1940, found in Usikov's private archive [4,5]. Brief review of that test can be also found in [8]. Still such radar was not developed by the time of Hitler's invasion of the USSR. The reasons of its failure were not in bad engineering but rather in the Orwellian circumstances of the USSR in the late 1930s.

As a result, experimental Zenit was briefly tested at the battlefield near Moscow in September 1941. Then new single-antenna radar Rubin (Fig. 5) was developed by LEMO in 1943 in Bukhara [4]. However its fate had been already decided. In January 1942, one unit of British radar GL Mk-II was sent to the USSR and immediately stolen from a UK cargo boat by NKVD; this radar was reverse-engineered within one month and then some 125 of them were produced as SON-2a [11].

II. Comparison of Zenit to Similar Achievements

From today's point of view, importance of Zenit test in 1938 was tremendous. Indeed, apparently all radars in service and in development at that moment (i.e., British Chain Home, German Freya and Seetakt, Soviet Burya, Rapid and Redut, and Doppler radar prototypes developed at the Tohoku University, Japan and in the laboratory of Marconi in Italy) were able to determine the azimuth of the target and either its range or elevation, while the third coordinate remained essentially undetermined. Unlike them, Zenit was able to overcome this drawback thanks to the lucky combination of two principal innovations: it used pulse method and worked with shorter than common waves of the 60-65 cm wavelength.

Pulse method itself was not absolutely new as it was first tested in Germany (Lorenz Co.) in 1936 and both in the UK, USA (L. Young and R. Page) and USSR (M. D. Gurevich, Jr. [8, p.52]) even earlier, in 1934. However by 1938 it had gained no significant attention of the military and civilian customers both in the USSR and abroad. Important exception was apparently the UK Chain Home early-warning network. It was using the pulse method from the start; however its ability to determine the target range and bearing was greatly degraded by the small resolution because of the 26-m (1936) to 10-m (1939) wavelength. The USSR experts then commonly viewed the CW principle of radar as more promising [1,4,8]. Initiative of Zenit development came from a civilian R&D laboratory, which was eager to explore the opportunities given by a freshly discovered pulsed mode of their original L-band split-anode magnetron operation. In this aspect Zenit was a champion – it was apparently the first ever radar with a pulsed magnetron source although the German Wurtzburg engineers were trying magnetrons around the same period.

Decimeter (L-band) waves were also actively studied at that moment in many countries. Anyway at the time of its first test Zenit apparently had the most powerful decimeter-wave source (3 kW) in the world, and by 1940 it used the source of 17 kW. Here it is worth reminding that the cavity magnetron at the 9.8-cm wavelength was invented in the UK in the beginning of 1940, improved for 10-kW power by the end of 1940, and used in radars since 1941 [3,10-13].

Before that, in the UK the Chain Home network operated with 26 m to 10 m wavelengths, and AMES-2 radar working with 1.5 m waves, for the Chain Home Low, appeared only in the end of 1939; the USA experimental 50-cm gun-aiming radar was developed by the Bell Laboratories only in 1940; in Germany the prototypes of the early-warning radar Freya and naval radar Seetakt used 2.4 m and 80 cm wavelengths, respectively, while radar Wurtzburg working with a shorter, 53 cm, wavelength had not appeared before 1939; and in Japan the waves shorter than 10 m and pulse method was apparently not applied in radar studies until 1941 [11-13].

III. Obstacles to Overcome: Technical and Not Only

As already mentioned, in the mid-1930s it was still far from obvious that the pulse radar technique had advantages before the CW radar. In similar manner, the use of waves shorter than a few meters in length was not yet considered as a mainstream of radar development. The USSR engineers and scientists from central laboratories in Moscow and Leningrad (Ioffe, Bonch-Bruyevich, Chernyshov, Korovin, Shembel, and others) argued that only the CW Doppler principle was promising and that the meter waves were better suited for applications [1-5]. This attitude was typical globally, and famous Home Chain radar network can be a good illustration. Therefore pursuing research into such a challenging direction in the conditions of Kharkiv was a matter of great courage and real insight into the problem.

Besides of technical problems, one should be reminded that the USSR was a totalitarian state. In 1932-1933, a genocide-scale famine devastated Ukraine when Stalin eliminated the grain market via high taxation and establishment of collective farms. Then the Soviet secret police GPU was ordered to confiscate, if the grain tax could not be paid off, all other foods from the farmers. As, besides of Ukraine, such killing measures were introduced only in the North Caucasus and a part of Volga region inhabited by the ethnic Germans, this artificial famine is believed to be the political action with a smell of ethnic cleansing. Today the most conservative estimations place the number of victims in Ukraine close to 4 million [14].

Fig. 5. A plaque on Slutskin's apartment house in Kharkiv with Rubin antenna.

The end of this brutal campaign saw independent farmers eliminated and the USSR being the largest grain seller in the world market. The obtained funds enabled the government to buy sophisticated machinery, equipment and even factories in the West, shaken by the global economic crisis, build power stations, and beef the military. In a way the UIPT scientists were also fed and their labs equipped at the expense of the starved to death peasants whose bodies were collected in hundreds every morning along the Kharkiv rim by the police patrols. Although very few people knew about the real scale of famine as any reference to it was strictly prohibited, the scientists of LEMO felt great concern of the situation [7].

Within UIPT, starting from 1935 the creative atmosphere was irreparably spoiled by brutal spy-mania and investigations of the Soviet secret police, renamed as NKVD. As explained in [4,5,7], their main target was Lev Landau and foreign scientists who were finally arrested, jailed, and interrogated in 1937-1938. In parallel, LEMO was forced to give all documentation on their magnetrons to the other USSR radar teams, which worked directly for the Red Army, such as R&D Institute no. 9 (RDI-9), in Moscow and Leningrad.

IV. Impact

At the national level, the work on Zenit served as a cradle for the whole microwave, antenna, and radar community in Ukraine [1-7]. Since the 1940s, Kharkiv has become and still remains the major center of research into microwaves, millimeter (mm) waves, and sub-millimeter waves in Ukraine. Indeed, thanks to experience with L-band magnetrons and Zenit in the 1930s, powerful mm-wave cavity magnetrons were developed by Slutskin in the late 1940s. Millimeter-wave radar was first explored already in the 1950s. These achievements paved the way to the appearance of other important establishments in Kharkiv after WW II. To mention only a few, these were the USSR Military Academy of Radio Engineering (1947), the School of Radio Physics at the Kharkiv National University (1952), the Kharkiv National University of Radio Electronics (1963), and the Hartron Space Control Systems Industry (1960). All these establishments and their offspring are at the core of today science and technology of the electromagnetic waves and their applications in Ukraine [6].

When Slutskin died from a heart attack in 1950, his department at UIPT was inherited by Usikov and Braude. In 1955, they became "fathers" of the Institute of Radio-Physics and Electronics of the National Academy of Sciences of Ukraine (IRE NASU, 1955). Later Braude was also co-founder of the Institute of Radio Astronomy (IRA NASU, 1985), also in Kharkiv.

As known, in 1938 Ukraine was a part of the USSR and remained such until 1992. At the level of the USSR, Zenit technology clearly demonstrated the merits of combined use of shorter-than-usual for the late 1930s waves and the pulse method, in the determination of all three coordinates of a flying aircraft. A crucial evidence of the role played by Zenit can be found in the capital Soviet source on the history of USSR radar – the book of Gen. M. Lobanov [8] who was supervising all gun-laying radar works before and during WW II. According to Lobanov, it was exactly in 1938 when, after four years of intensive work on CW radar, the main military laboratory RDI-9 switched to development of pulse radar technology.

Interestingly, a 1962 journal article (precursor of book [8]) of Lobanov was extensively cited in the famous work of J. Erickson [1] and his later book chapter [2], where Zenit was also mentioned, together with its test in October 1938.

It must be also emphasized that the negative evaluation of Zenit given in the generally well documented and in all other aspects accurate book of L. Brown [10], with a reference to the book of Lobanov, was erroneous. Lobanov had devoted three full pages to Zenit, describing this achievement with strong sympathy and concluding with very high evaluation. It is apparent that, unlike Erickson's thorough study of preceding Lobanov's article, Brown had never read the book of Lobanov except perhaps of translation of selected pages.

This overlook was finally corrected and important role of Zenit was fully acknowledged in the later encyclopedia of radar history worldwide of R. Watson [11] – see pp. 292-296.

Finally, for the international technological development, Zenit remained largely unknown and so had little or no impact. Still there exists a certain mystery. An article was published in the Ukrainian newspaper “Evening Kharkiv” in 2000, stating that the German intelligence, apparently political wing of SD, was aware of the radar work in Kharkiv and put some efforts to obtain information about it. The journalist claimed that in the 1970s he interviewed the pre-war and wartime Soviet minister of communications, Signal Corpse Marshal I. Peresypkin [9]. The marshal showed him a German intelligence report with a handwritten note of Hitler, dated April 4, 1938 and ordering to send the best spies to Kharkiv for radar intelligence. This could be connected to the development of similar system Wurtzburg (Fig. 6) with 53-cm wavelength and 3-m parabolic antenna.

Today one can also say that besides of above-mentioned points, the success of Zenit demonstrated one other principle of deep social meaning. Highly innovative R&D, even in defense-related area, has better chances for a rapid progress at a civil laboratory than at a military one. This was never admitted in the highly militarized and infested with spy-mania USSR, however was well known circumstance in the UK and the USA where famous civil organizations such as the Telecommunications Research Establishment and the Radiation Laboratory at the Massachusetts Institute of Technology, respectively, had played crucial role in the acceleration of radar developments during the WW II [12,13].

Fig. 6. German gun-aiming radar Wurtzburg, 1944.

All mentioned above is only a part of the whole story. Still it shows why radar Zenit is the first Ukrainian IEEE Milestone.

REFERENCES

[1] J. Erickson, "Radio-location and the air defence problem: The design and development of Soviet radar 1934-40," *Science Studies*, vol. 2, pp. 241-268, 1972.

[2] J. Erickson, Chapter 16 in *Radar Development to 1945*, ed. by R. Burns, Peter Peregrinus/IEE Publ., 1988.

[3] S. S. Swords, *Technical History of the Beginnings of Radar*, Peter Peregrinus/IEE Publ., 1986, section 4.7.

[4] A. A. Kostenko, A. I. Nosich, and I. A. Tishchenko, “Development of the first Soviet 3-coordinate L-band pulsed radar in Kharkov before WWII,” *IEEE Antennas Propagat. Mag.*, vol. 44, no. 3, pp. 28-49, 2001.

[5] A. A. Kostenko, A. I. Nosich, and I. A. Tishchenko, “Radar prehistory, Soviet side: development of the first 3-coordinate L-band pulse radar in Ukraine in the late 1930’s,” *IEEE Antennas Propagat. Symp. Digest*, Boston, vol. 4, pp.44-47, 2001.

[6] A. I. Nosich, Y. M. Poplavko, D. M. Vavriv, and F. J. Yanovsky, “Microwaves in Ukraine,” *IEEE Microwave Mag.*, vol. 2, no 4, pp. 82-90, 2002.

[7] A. I. Nosich and A. A. Kostenko, "In the labor people's name: development of 60-kW magnetrons in the artificial famine plagued Ukraine in the early 1930s," *Proc. Int. Conf. Origins and Evolution of the Cavity Magnetron (CAVMAG-2010)*, Bournemouth, pp. 82-88, 2010.

[8] M. Lobanov, *The Beginning of the Soviet Radar*, Moscow, Sov. Radio Publ., 1973 (in Russian).

[9] V. Artemenko, "Watched by Muller," Newspaper “Vechirny Kharkiv” (Evening Kharkiv), no 128 (8189), page 4, 16.11.2000 (in Russian).

[10] L. Brown, *A Radar History of World War II: Technical and Military Imperatives*, Taylor and Francis Publ., 1999.

[11] R. C. Watson, Jr., *Radar Origins Worldwide: History of Its Evolution in 13 Nations through World War II,* Victoria, Trafford Publ., 2009.

[12] IEE Proc. A, Special Issue on Historical Radar, vol. 132, no 6, 1985.

[13] R. Buderi, *The Invention that Changed the World*, NY: Touchstone, 1997.

[14] T. Snyder, *Bloodlands*, NY: Basic Books Publ., 2010