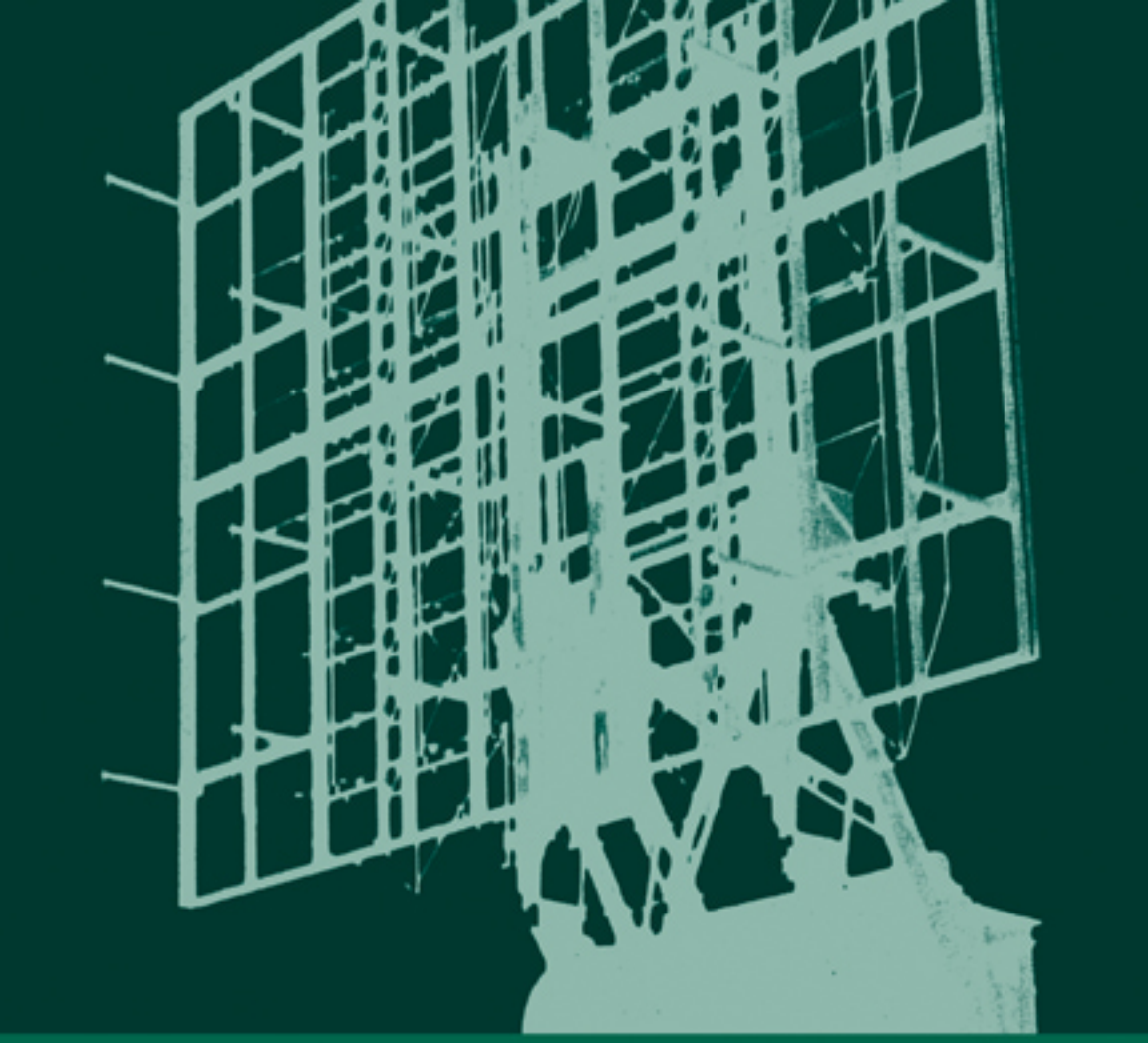

GEMA: BIRTHPLACE OF GERMAN RADAR AND SONAR

HARRY VON KROGE

IoP

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FOREWORD

The location of targets by means of sound and radio waves represents an important part of the many technical advances of this century. I had the good fortune to experience this work from the beginning with my friend, Hans-Karl Freiherr von Willisen, and to have contributed something to its development. It was our privilege to have enthusiastic scientific and technical co-workers at our side with whom we quickly converted Dr Rudolf Kühnhold's ideas into practice. In the course of this work we learned that Christian Hülsmeyer had successfully demonstrated thirty years earlier the location of ships with the primitive radio methods of the time. The importance of his invention was not realized at the time, and he found no employment for his 'Telemobiloskop'.

A decisive contribution to our activities at GEMA was made by our scientific co-workers Dr Theodor Schultes, leader of the high-frequency laboratory, and Dr Walter Brandt, leader of the low-frequency laboratory. They were model team-chiefs from whom fundamental developments in radar and sonar originated.

I am grateful and pleased that Harry von Kroge has finally, after long years of research, been able to tell this detailed and significant story.

I hope this book with its report of an interesting part of German technical history achieves a well-deserved success.

Paul-Günther Erbslöh
Berchtesgaden 1998

TRANSLATOR'S PREFACE

The story of radar's invention and development in the years preceding and during World War II is a confused one, with serious gaps in a record confounded by error and tinged with mythology. This unfortunate state of affairs is the direct consequence of the severe secrecy that was imposed on this strange new vocation. For many years the people writing the history of radar had been participants in its formation and maturation, a circumstance that gave weight to their presentations but that invariably skewed their articles and books toward narrow points of view. Given that even the descriptions of the Allied efforts are covered in a highly irregular way, it is hardly surprising that those of the Germans and Japanese are but poorly covered, and are certainly not well known to English-language scholars. Many of their records were destroyed during the war, and the industrial research communities that built this equipment were disrupted and scattered. Their immediate postwar world left them with problems more pressing than writing history.

Former Telefunken people have given their company, famous for the Würzburg gun-laying and Lichtenstein airborne radars, some coverage, but the origins of the equally famous Freya air-warning and Seetakt ocean-surveillance radars are confused, even in Germany. It is generally reported, although not correctly, that their manufacturer, GEMA, an acronym for Gesellschaft für elektroakustische und mechanische Apparate, was only a cover for ownership by the German Navy. That they built the first functioning radar is appreciated almost nowhere; that their equipment during the first years of the war was the best of its kind will be disputed hotly by many, but the evidence justifies such a statement. But GEMA personnel wrote no histories.

Sonar does not rank in importance with radar, but histories of it are entirely from the British and American viewpoints. GEMA also designed and manufactured Germany's sonar and the development of the two devices is remarkably interrelated.

The reader will find two valuable topics discussed here: (1) a technical description of the evolution of GEMA's radars and sonars, and (2) a detailed history of an industrial corporation in wartime Germany. The former is instructive in

comparing the development of similar equipment among the Allies. The second presents remarkable and rare material about how industry was carried out under such singular operating conditions.

The author has devoted decades to seeking out persons important to GEMA's history and in so doing uncovered a wealth of widely scattered documentary material, generally in the hands of individuals, not in formal archives. His work became known to some of us outside Germany a few years ago in manuscript form and was immediately recognized for its importance. The late Dr John H Bryant, not being fluent in German but seeing the great value of the material, had the text translated by Dr David Learned, MD, who spoke it sentence by sentence into a tape recorder. The results were transcribed and edited by Bryant. This translation, though useful to Bryant, was not suitable for publication and has not been used or referred to in providing this version.

The reader will find that we have not been consistent in dealing with names of organizations and apparatus. A translated form is given for some, others are left in German when the word or phrase has or develops currency during the reading and where a substitute English word proved to be awkward. The Subject Index can be used to relate the two.

One cannot present the history of radar without touching on technical matters to some extent, and the level at which to tell the story is a difficult problem for the author. Radar history has lessons valuable for electrical engineers, physicists and military personnel as well as historians concerned with technology, industry, armaments and strategy. Add to them laymen of wide interests, and the author will be puzzled as to what to include. The historian will be confused and irritated by extensive technical descriptions; the engineer will react similarly to their omission. Some technical matters are aimed at all readers, but other parts that are judged of little interest except to engineers and physicists are marked in **boldface** and can be skipped without losing the thread.

The translator and author wish to thank Mr F A Kingsley and Mr John Street for their careful reading of the text. Their comments resulted in numerous improvements.

Louis Brown
Washington, 23 September 1998

INTRODUCTION

A number of circumstances caused me to probe into the history of a corporation that had considerable importance for radar technology in Germany from its beginning until 1945. I had an interest in radio even in my school days. During and immediately after the war I lived with my grandparents on a farm in the so-called Kehdinger region between Stade and the mouth of the Oste on the lower Elbe. There were in that region numerous air warning and fighter control stations constructed for defence and that I could reach either on foot or on my bicycle. The stations were equipped during the course of the war with ever more complicated communication and radar apparatus, which I found particularly interesting.

In retrospect it is scarcely understandable how I, especially after 1944, could observe this equipment unmolested for hours, sometimes for days, equipment covered by the strictest secrecy. I watched not only the installation, routine operation, maintenance and crew training but also saw operation in response to air attack. I can perhaps explain this by noting that in 1944 the sharp young soldiers of the Luftwaffe air-warning service had been removed for more heroic duties at the front and replaced by men unsuitable for service there and by women of the Luftwaffe and the Reichsarbeitsdienst (National Labour Service), whose friendship I gained through gifts of produce from my grandfather's farm, which kept the friendly group in good humour. I even visited Flakhelfer (teenage soldiers) at an antiaircraft gun position in the uniform of these young people in order not to stand out.

Many experiences made a strong impression on me, especially in connection with modification and expansion when a lot of equipment could be seen. I gained a rough understanding of the various pieces and their function by watching and listening to the maintenance troops and company technicians. In February 1945 I was able to see the transmitter of a panoramic radar equipped with a spark modulator installed and tested. My experience with spark coils in physics class made this appear antiquated. I remembered that, besides the names of the well known producers, there appeared the name GEMA and that the equipment of this company carried the marking 'bya' rather than a company logo.

I experienced the end of the war on 1 May 1945 when the town of Stade was given up without a fight and British troops occupied the Kehdinger land at the mouth of the Elbe. As it had been ordered earlier that Hamburg was to be defended, many German soldiers on the west bank of the river crossed over quickly. Inasmuch as there was no orderly retreat, a number of vehicles were abandoned, some being left on our property near the Elbe. Next to partially destroyed trucks stood two vehicles that were loaded with equipment that I recognized from my visits to the radar positions. With the help of a Polish prisoner whom I knew well I was able to salvage some of it and hide it from the British troops. It must have been a lasting impression formed earlier that caused me to pick apparatus bearing the marking 'bya' for hiding. The hiding place was so good that it was never discovered by the changing occupation troops in our vicinity. The hidden sets took up plenty of room and some weighed hundreds of pounds. Only my youthful unconcern allowed me to sleep well. I would not have been the only one to suffer, if my secret had come to light.

In the remains of a workshop in a destroyed part of the Hamburg Naval Arsenal and at a damaged radar position I found, before the British, the elements from which I gained my first knowledge. I discovered the meaning of the acronym 'GEMA' to be 'Gesellschaft für elektroakustische und mechanische Apparate m.b.H.', that they were located in Berlin, and I was able to identify part of my carefully listed equipment. I cautiously put my questions to soldiers of a technical company of a Luftwaffe research institute, who had been interned by the British in our vicinity in the summer of 1945. Because one could not continue lessons in secondary school in town until the fall, my mother allowed me to take private lessons from suitable members of this company. I found sufficient trust in one of these teachers to show him part of my secret hoard. At night I moved by myself the components of a GEMA N-Gerät into a remote room. In meetings that were supposed to cover my school studies my 'tutor' taught me the secrets of this equipment, a GEMA receiver and indicator. For the first time I received exact information about a part of my treasure.

(I insert here the reason why a company name was encoded in two or three letters: for reasons of secrecy the name of the producer could only be given in coded form. The Heereswaffenamt (Army Ordnance Department) in Berlin from 1940 until 1945 produced lists of manufacturers of weapons, munitions and equipment as secret documents, from which the name and address of the producer could be found.)

After capitulation the situation under British occupation loosened relatively quickly. Our vicinity was completely freed by the end of 1945, and the last German military personnel were released. I ventured slowly to bring my equipment out of hiding, and things again went to my advantage.

At the beginning of 1946 my grandfather employed a farmhand, who had worked during the war in radar service. He was by training a pastry cook and his radar knowledge came only from Luftwaffe drill. Although not an expert, he enhanced my knowledge as best he could and together we studied my equipment.

The solid construction always pleased me, even when the consequent weight plagued me. We learned that I possessed the electronic basis of a GEMA Freya radar. There were two or three units for some items, and in boxes were packed diverse receivers, transmitters and cathode-ray tubes.

Under the leadership of my physics teacher, nicknamed 'Pikkolo', and with the help of friends I was able to put the receiver and indicator into operation, but of course, there was nothing to receive. By inserting another receiver and making a small alteration, I was able nevertheless to receive the signals from Hamburg's first ultra-short-wave transmitter in 1949. This seemed legal to me, and I demonstrated it to everyone, both acoustically and visually. I would have liked to try out the transmitter but refrained, because it was forbidden and I was afraid of the high anode voltages, which was just as well. I was able to control my passion for unqualified tinkering and lovingly cared for the equipment, for which I had my reward years later.

In 1952 I became active in the Institute for Ionospheric Research in the Max Planck Institute as part of my engineering studies. There Professor Walter Dieminger, scientist and leader of the institute, gave my professional career its final stamp. In his laboratory I found what I wanted: radar technology in its purest form with equipment to use. My first work brought me into contact with GEMA equipment and the peculiarity that had shocked me earlier because I had held it to be antiquated: the spark gap.

High-power pulse transmitters were needed in order to measure the night-time propagation paths of the former Northwest German Broadcast network. For this purpose transmitters from the GEMA radar Freya were rebuilt with 500 kW spark-gap modulators, a technique proposed during the war by Professor Erwin Marx for high-power GEMA modulators, the installation of which I had watched with amusement at one of the radar stations I had visited.

I gained at this laboratory a unique introduction to the theoretical and practical techniques of transmission and reception, as well as of timing or ranging for ionosphere sounding. Through discussions with the accomplished people there, and by perusing the abundant documentary material, I was able to complete my knowledge of GEMA equipment. After altering my own equipment to the 2 m band, on a frequency for which I had earned an amateur license, I succeeded in determining the range and direction of aircraft with my GEMA equipment, using a home-made Yagi antenna. This kind of operation was, of course, not allowed with my license, so I tried it out only briefly. After that I used this modified set for longer periods to sound the ionosphere with single short-wave pulses.

Further experiments with my GEMA set had to be abandoned when I began work in Hamburg. Once I had moved part of my heavy equipment, but never again. I had to dispose of such gear but could not bring myself to part with the GEMA range-measuring delay unit marked 'Messkette' (measuring chain) or 'UK' until I had calibrated it with modern equipment. One such circuit that came from the earliest years of the company allowed me to convince myself of the technical mastery the company had realized.

Both professionally and personally I have examined many pieces of radar apparatus manufactured by competent firms in the period up to 1945 and do not want to make comparisons, as all were marked by German precision and workmanship, but GEMA products were known from the beginning for their enduring and robust construction.

The decision to pursue the history of GEMA came to me in the 1960s through a discussion with Dr Hans Rindfleisch, at the time Director of North-West-German Radio Company in Hamburg. I received from him the first concrete information about the connection between the former Naval Nachrichtenmittel-Versuchsanstalt (NVA, communications research laboratory) in which Dr Rindfleisch had been active, and the firm Tonographie, from which GEMA had grown, founded by the two owners of Tonographie, Paul-Günther Erbslöh and Hans-Karl Freiherr von Willisen. I learned from him that GEMA had been liquidated in 1945 and that there had been an associated company Tonographie, which von Willisen then headed in Wuppertal.

I am still moved today by the moment when Dr Rindfleisch mentioned Tonographie, a firm in which I then had professional connections, and soon my discussions were extended to none other than von Willisen himself. Subsequently I had many conversations with him about GEMA. He had attempted to put together a history of the company, but his premature death in 1966 prevented the completion of this task, and this unexpected death put an altogether too early end to our extensive conversations. He and Dr Rindfleisch have earned my thanks.

It has been tedious to ascertain the exact chronology of GEMA's development. The limits of the collaboration with the various naval units, especially with Dr Kühnhold in Kiel, were broad and ill defined. It was my special desire to recognize in a proper manner this collaboration as well as that with other companies and scientific institutes.

At home and abroad there have been many publications about radar. In general they represent GEMA as a cover for the Navy's production of radio-location equipment. This statement comes superficially from the early collaboration with the NVA, but it is not true. This situation gave me an additional reason to probe deeper into the firm's history.

From the many discussions that I had and from the many authentic documents that I located during my studies, I obtained the information needed for a history that would closely approximate the truth. Besides von Willisen, other GEMA personnel have provided much support through their interviews and written memoirs and by furnishing documents and pictures. I especially want to thank Mr Erbslöh. I also want to thank Dr Walter Brandt, who made himself so valuable to the company. There were also plenty of special reports from Mr Röhrig and Mr Henke for which I am especially grateful. Mrs Rhein, von Willisen's secretary for many years, was able to locate important documents from the papers of her former employer. For her help I am much obliged. Until Germany's reunification it was impossible to conduct research at the company's previous location in East Berlin, but a very agreeable working relationship developed after the archives of

east and west were joined. Dr Czihak and his co-workers deserve my thanks for the splendid way they helped in my search for old papers.

After gathering the data and facts about GEMA, it was not easy to avoid a comparison with German and international literature, but that is not my intention. Indeed I shall be pleased if my presentation allows the reader to make this comparison for himself. To this purpose I have worked out the continuity and timing more accurately than might seem necessary.

In order to prevent the size of this book from exceeding acceptable limits, only the crucial phases of the company's evolution and of equipment development are included. The diversity of the apparatus developed and manufactured by GEMA does not allow one to describe it all. It is my intention to make this good for the interested reader with a later supplement.

CHAPTER 1

IN THE BEGINNING WAS AN IDEA

After his graduation from Göttingen in physics Dr Rudolf Kühnhold accepted a position in 1928 as scientist at the Navy's Nachrichtenmittel-Versuchsanstalt (NVA). This institution had been organized at Kiel in 1923 for research and development of naval communications. An auxiliary station was found at Pelzerhaken near Neustadt on the Lübecker Bucht (Lübeck Bay).

Underwater sound was, from the start, a special assignment for NVA. In addition to improving the performance of the existing acoustic telegraph and developing directional capability for underwater noise receivers there was an urgent need for a method of directing naval fire at surface or underwater targets using sound for direction and ranging. This task had been given to it by the Torpedoversuchsanstalt (Torpedo Research Laboratory, TVA), which needed such a device for the precise aiming of its missiles.

This was a challenge for the young scientist, who became the leader of the acoustic group. He could draw on very little previous work, and much basic research would be required for such a project. First the propagation of sound in water had to be understood in order to develop the theoretical framework on which the design depended for the complex acoustic, electric and mechanical systems that would transmit and receive directed sound waves.

The NVA had limited resources for conducting the necessary experiments and building such new equipment, and Dr Kühnhold was dependent on qualified firms for their collaboration. The first fundamental measurements used a fathometer from the Atlas Company, which was already in use by the Navy. At the same time they acquired a 30 kHz sound generator in an experimental stage with a transducer from the French company SCAM, according to Langevin-Florison. This work proceeded slowly because only a few boats could be made available and the weather often interrupted. Time was also lost when it was realized that the lower salt content of the Baltic relative to that of the North Sea had important effects on their data. Nevertheless, Kühnhold's group succeeded by 1933 in gaining a

substantial understanding of the propagation, diffraction and echoing of sound in water and a knowledge of the natural noises of the ocean.

These experiments showed that the demands of directing the fire of naval ordnance could not be met with existing sound equipment. The TVA insisted on an accuracy of 1° at a range of 7.5 km. To achieve this required a completely new kind of apparatus. Kühnhold did see the realization of his ingenious idea for determining the lateral deviation of a target by using two separated microphones connected to amplifiers that showed respectively the sum and difference of the signals. In 1931 he patented this sum–difference method, which was employed not only for sound location but later also for radar.

Beginning in 1933 Kühnhold, who had become Scientific Director of NVA by then, had decided to try radio waves in place of sound for target location. The Pintsch Company in Berlin was developing, with the assistance of Professor Karl Kohl, a 13.5 cm transmitter and receiver using Barkhausen positive-grid tubes, the transmitter yielding 0.1 W continuous power. NVA ordered this equipment from Pintsch and had the transmitter and receiver mounted to parabolic-mirror antennas of six-wavelength diameter. In early fall 1933 the first experiments were carried out between the NVA building and the naval arsenal, located about a mile away. The transmitter stood on the NVA building, and its signal was easily received across the harbour at the arsenal. Reflections from either the building or ships were not observed, no matter how the antennas were rotated relative to one another.

It was a great disappointment when there was no evidence of reflections when the antennas were pointed directly at large ships. Kühnhold blamed these negative results on the low power of the Pintsch transmitter, but an immediate increase in the power was impossible, owing to inherent limitations of the Barkhausen tube. Professor Kohl estimated that the time needed to obtain high-power tubes for centimetre waves was a decade, but Kühnhold did not allow himself to be discouraged by these unsuccessful reflection experiments, and he placed an order with Pintsch to improve the power of their transmitter and the sensitivity of their receiver.

In addition to the experiments in collaboration with Pintsch, Kühnhold discussed the problem with established electronics companies, in particular with Telefunken. Because no one realized the depth of his ideas and thoughts, and because reflection experiments with centimetre waves were considered out of the question at the low power levels then available, he found no support.

CHAPTER 2

THE ORIGINATORS

Shortly after the end of World War I two Potsdam students discovered a common interest in wireless telegraphy and telephony. Paul-Günther Erbslöh, born in 1905 in Düsseldorf, came to Potsdam in 1917 through the transfer of his father, a high-level state official. Hans-Karl Freiherr von Willisen, born in 1906 in Berlin-Charlottenburg, grew up in a Prussian officer's family and studied with Erbslöh at the Realgymnasium in Potsdam. After the war von Willisen, by way of an intermediary friend of his parents, came into possession of a Type E 170 intermediate-receiver of the German Telephone Company (DE-TE-WE). During the war this receiver had been part of an Army wireless station and allowed earphone reception in the 600 to 150 m band (500–2000 kHz). Not only that, young von Willisen received a box that was richly filled with AEG and TKD triodes and many other radio and military components, which impelled him and his friend Erbslöh toward intensive electronic activity.

Von Willisen connected his receiver to various antennas and listened to what was on the air in the bands available, and Erbslöh, after various more or less successful experiments, built a similar receiver. They used the army triodes to build an amplifier that markedly raised the sensitivity of the receivers. After many failures and much effort the two mastered the techniques of feedback, which allowed them to build a regenerative receiver that left the sensitivity of their old sets in the shade and opened enormously the range of wireless signals they could hear. Improvements that could not be made from the provisions of their box of spares could be made through the purchase of components at nearby electrical stores, there having been many stores in Berlin that sold components from surplus military radio apparatus.

Von Willisen had learned Morse code, so it was inevitable that they should read commercial wireless traffic, both domestic and international, which led them quickly to discovering the existence of the stations at Nauen and Norddeich. After a number of unsuccessful bicycle trips von Willisen finally gained access to the

transmitter personnel at Nauen and used them to quench his thirst for knowledge about the generation and radiation of radio waves. He had already learned the basis of continuous-wave transmitter operation from experiments with feedback.

The two heard the broadcasts of the Königswusterhausen station from the very beginning, which they used to improve the quality of the audio reception of their sets. They were, however, unable to establish personal contact with the operators, as they had at Nauen.

The first official German radio broadcasts came at the end of October 1923 from the studio of the phonograph record company VOX and were heard by the fifth-form boys, Erbslöh and von Willisen. Through their practice as amateurs and from their collecting and studying of foreign and domestic publications and bulletins, they gained an ever-increasing knowledge of the field of electronics as well as a good understanding of the basic physical principles. None of this was beneficial to their school work.

Von Willisen became a wizard at quickly finding people competent to answer their questions about problems that arose and extracting answers from them. In addition to transmitter and receiver technology he became interested in sound reproduction and built an amplifier and several microphones that worked rather well. A few days after the first broadcast von Willisen was able to establish contact with the technical leadership of VOX-House, which consisted of Director Scheffer and Engineer Heckmann. He and Erbslöh were able to participate in the trials of the recording apparatus of this station. After that it proved fairly easy to establish contact with the leader of the Königswusterhausen station, Erich Schwarzkopf. With Erbslöh he designed and built, among other things, a microphone that was made of three microphone capsules of the carbon button type, which were in common use in telephone sets. Its frequency response was corrected through tedious threading and stuffing of the region between the covering grid and the carbon diaphragm with wool. They embedded the three thus-improved capsules in felt surrounded by a wooden ring on a dowel as a handle. The microphone resembled visually the signal upheld by a railway platform master to indicate 'proceed' and was named just that: 'Abfahrtskelle'. The quality notably exceeded that of previous microphones.

Erbslöh and von Willisen found a friend in Erich Schwarzkopf, who was interested in an electrical pick-up from phonograph records, and engaged the two with his ideas, and in a remarkably short time the two had developed one. They cleverly mounted a needle onto the diaphragm of a telephone earphone, and the electrical pick-up was born. The converting of phonographs from acoustical to electronic soon brought them a nice income, and they often sold amplifiers and loudspeakers too.

Erbslöh and von Willisen then easily reversed the process. With a sharp sapphire mounted on the telephone earphone diaphragm they cut records on blank wax discs by applying the output voltage of an amplifier to the device. Since the time of Edison, Berliner and Pathe, discs had been recorded by purely acoustic methods, and corrections to the recorded frequencies were not possible. Record-