Adv. Radio Sci., 21, 65–75, 2023
https://doi.org/10.5194/ars-21-65-2023

Advances in Radio Science
Open Access Proceedings

Egbert von Lepel and the Invention of the Spark-Gap Transmitter

Wolfgang Mathis

DEI, Fakultät für Elektrotechnik und Informatik, Leibniz Universität Hannover, Hanover, Germany

Correspondence: Wolfgang Mathis (mathis@tet.uni-hannover.de)

Received: 7 February 2023 – Accepted: 16 March 2023 – Published: 1 December 2023

Abstract. On 29 October 1923, radio broadcasting or "Rundfunk" was officially opened in the Voxhaus in Berlin and thus the new communication medium was now also available in Germany, but later than in other countries such as the US and the UK. However, first experiments with wireless telephony, which is the technical basis of this medium, were carried out more than ten years earlier (Pungs, 1922; Mathis, 2019; Titze and Mathis, 2020; Mathis and Titze, 2021). One of the pioneers of this technology was the German Egbert von Lepel, who developed in 1907 a new concept of wireless transmitters that was also suitable for use in wireless telephony. The concept later became known as the quenched spark-gap transmitter ("Löschfunkensender") or "Singing Spark" transmitter where a specific variant was developed by the Gesellschaft für Drahtlose Telegraphie (GDT: "Wireless Telegraph Society"), System Telefunken. This article discusses the history of this type of transmitter using new historical sources from national and international archives. It turns out that contrary to what is known on this subject from almost all publications on the history of early wireless technology, the German Imperial Patent Office decided in January 1911 that Lepel's patent was granted as the most fundamental for quenched spark-gap transmitters. With the disclosure of this important historical source, the question of the origin of the invention of the quenched spark-gap transmitter must be reassessed.

1 Introduction

Radio broadcasting, known in Germany as "Unterhaltungsrundfunk", was officially started on 29 October 1923, where "Rundfunk" had already been mentioned in 1919 by Hans Bredow (1879–1959) (Bredow, 1920) and by Hermann Thurn (1877–1932) (Thurn, 1920) for civilian use of wireless telegraphy. The radio station, broadcasting on medium wave at 749.5 MHz, was set up in the Voxhaus in Berlin on the top floor of the central building of a German record company. The tube transmitter was built by Friedrich Weichart (1893–1979), an electrical engineer at the German Reichspost, within 14 d (Weichart, 1930, 1997). The opening of radio broadcasting in Germany came quite late, because the first radio stations were already licensed in the Netherlands (de Boer, 1969) and the USA in 1919 (Kintner, 1932) and 1920 (Douglas, 1987), respectively, and in the UK in 1922 (Crisell, 1997). Since Germany, together with the USA and the UK, was one of the leading countries for wireless telephony, it could not be due to technical reasons. The late opening in Germany was also related to some restrictions of the Versailles Treaty (Der Friedensvertrag von Versailles, 1925) as a result of the First World War, although it was more a consequence of the policy of the Reichstelegraphenverwaltung (RTV) (Telegraph Administration) as the supervisory authority for wireless in Germany.

One of the key persons in the conversion of the war economy in the field of wireless telegraphy and telephony to civilian applications in Germany was Hans Bredow, who until March 1919 was the technical director of the Society for Wireless Telephony (Gesellschaft für Drahtlose Telegraphie, GDT), System Telefunken (renamed "Telefunken" in April 1923), the leading company for wireless telegraphy in Germany. In 1919, Bredow had been appointed as Ministerial Director in the German Reichspost Ministry (RPM) in order to bring the wireless stations, which had been occupied by soldiers' councils after the end of the war, back under state control. Bredow was successful and henceforth pursued his own strategy of using wireless telegraphy and telephony for civilian applications, developing plans for the dissemination of political, social and business news in cooperation with newspaper and commercial companies. To do this, these companies had to rent wireless receivers that could only be used for fixed frequencies, in accordance with the rental telephone concept, which had already been implemented by RTV. Al-

though Bredow's department of the RTV started successful experiments where radio transmitters from Königs Wusterhausen (Funk, 1927; Suckow, 2008) were used, negotiations with the newspaper companies failed (Berger, 1998). But the Eildienst für amtliche und private Handelsnachrichten GmbH (Eildienst) (Express service for official and private business messages) founded in Juli 1920 for delivering business news via wireless media was ready for a cooperation with RTV and a "Funkwirtschaftsdienst" (radio service for business news) was established (Klöcker, 1926). In a contract from July 1921, the Eildienst agreed to cover all costs of the RPM, a consortium of companies (Telefunken, C. Lorenz AG, Dr. Erich F. Huth Signalbau AG) had to ensure the construction of 1000 radio receivers and after a further delay, the "Wirtschaftsrundspruch" (economic business service) started on 1 September 1922 with periodic broadcasting of business news to around 400 customers 100 locations (Thurn, 1921; Lerg, 1963, pp. 1120–113).

Whereas Bredow, who became "Staatssekretär" (Secretary of State) in the RPM in 1921, pursued his goal of commercial use of wireless telephony so-called radio amateurs pushed the idea of radio broadcasting for all, having in mind the opportunities for radio amateurs in the United States. The first radio clubs were founded in Coburg (1919), Hamburg (1923) and in the same year in Berlin by Eugen Nesper (1879–1961) (Goebel, 1983) the "Deutsche Rundfunk Club" (German Radio Club) (Nesper, 1950, p. 103). Also in 1923 Nesper founded the magazine "Der Radio-Amateur" (Nesper, 1923a) and published the book "Der Radio-Amateur, Broadcasting" (Nesper, 1923b). Although radio clubs soon had more than 10 000 members and radio amateurs had contacts with RTV, general broadcasting licenses did not yet exist. It was only after Nesper, together with Sigmund Loewe (1885–1962), Otto Kappelmayer (1894–1971) and the young Manfred von Ardenne (1907–1997), organized a meeting with Reich President Friedrich Ebert, the Prime Minister of Prussia and some ministers of the German government, where wireless telephony and the idea of radio broadcasting were presented, that the matter came up moving. Bredow was not informed about the meeting, but still came under pressure (Nesper, 1950, pp. 103–104). This ultimately led to him initiating the development of a tube transmitter in early October 1923, so that on 29 October 1923 the official start of radio broadcasting in Germany was announced. Later, Bredow reinterpreted the actual events and declared himself to be the real driving force behind the realization of radio broadcasting in Germany (Bredow, 1927), which has been the common view, at least in the media, for many decades (Mehle, 1955; Ross, 1966; Lerg, 1980).

Radio broadcasting benefited not only in Germany, but also in other countries from the conversion of military technology into civilian technology, with wireless telephony being the basic concept of this technology. The roots of wireless telephony go back to 1903 and 1904, respectively, when the first two concepts were developed by Valdemar Poulsen (1869–1942) (Poulsen, 1903) with his spark transmitter and Ernst Alexanderson (1878–1975) with his alternator (Brittain, 1992). The latter concept was suggested by Reginald Fessenden (1866–1932), who used it in his experiments in the transmission of speech and music in 1906 (Seitz, 1999). As early as 1904, Poulsen was successfully transmitting speech with his radio transmitter. A disadvantage of both concepts was the very large and heavy transmitters. In 1910 Lee de Forest experimented with wireless telephony (de Forest and Seibt, 1910). A suitable alternative concept was developed in 1907 by Egbert von Lepel (1881–1941), who became an inventor with his own laboratory in Berlin after having to leave the GDT in 1905. However, von Lepel did not have a solid education in electrical engineering, so he did not understand the physical basics of his transmitter. Independently of him, Max Wien (1866–1938) investigated the physical behavior of short-gap spark electrode assemblies and found that it had advantages over wide-gap Braun-Marconi transformers. Although Wien never described or built a complete transmitter, Wien became the inventor of the transmitter that was built by the GDT in 1908 and marketed very successfully under the name "Löschfunkensender" (spark-gap or quenched spark-gap transmitter).

In fact, the spark-gap transmitter concept is closely related to the previously unknown or misinterpreted von Lepel transmitter (Friedewald, 1999). Instead, publications on the history of wireless telegraphy and telephony follow the explanations of Georg Graf von Arco (1869–1940) (Fuchs, 2004), who had been technical director of the GDT since 1903 and was von Lepel's supervisor during his GDT time. Hans Bredow was von Lepel's colleague at GDT from 1904 to 1905 and became technical director of GDT in 1908 before the spark-gap transmitter was tackled. That is why Bredow is also responsible for the fact that von Lepel's performance has not been recognized so far.

In this article we study the scientific and business career of Egbert von Lepel and in particular his research and development of his spark gap transmitter and his patent dispute with the GDT regarding the spark-gap transmitter concept. In particular, it should be clarified which patent was valid in the patent courts involved and what consequences were drawn from these decisions. Previously unknown archive materials are used to answer these questions.

2 Some Biographical Notes on Egbert von Lepel

Egbert von Lepel was born on 30 September 1881 on the German Baltic Sea island of Usedom and belonged to the old aristocratic family von Lepel, who lived in north-eastern Germany. Few details are known about his youth, but as usual he was educated by tutors on his parents' manor in Neuendorf/Gnitz in Prussia (Hansert and von Lepel, 2008, pp. 188–189; Schröder, 2007). But as in other wealthy noble families in Prussia, an officer's career in the Prussian army was prob-

ably planned for Egbert von Lepel. With regard to Egbert von Lepel's later profession, it seems interesting that Franz von Lepel (1851–1906) (Hansert and von Lepel, 2008, p. 146), a relative from another part of his family, had a doctorate in chemistry before taking over the manor. But even after that, Franz von Lepel studied chemical processes in sparks and thunderbolts, as well as the oxidation of nitrogen by electric sparks, using Rühmkorff's spark coil. Evidently the young Egbert von Lepel had contact with Franz von Lepel, who even showed and explained his experiments to him. Therefore it could be that young Egbert had some knowledge about spark inductors from a young age.

At 20 years Egbert von Lepel did his military service in the 2. Pommersche Ulanen-Regiment Nr. 9 from October 1901 to 12 September 1903 where he became a lieutenant. In an interview with Egbert von Lepel in 1934 with "The Daily Gleaner", there is a remark that he was educated at the "University of Berlin", which can only be the "Technische Hochschule Charlottenburg/Berlin". At that time Adolf Slaby (1849–1913) was conducting experiments with wireless telegraphy and if Egbert von Lepel had received knowledge about spark coils from Franz von Lepel, contacts with Adolf Slaby's group were possible. Without a formal degree, Egbert von Lepel was hired by the GDT in early 1904, although the technical director, Georg Graf von Arco, had applicants take rigorous exams before hiring candidates. A technical briefing followed and then von Lepel became a member of a group of engineers from the GDT, which provided the Russian Baltic Fleet with wireless telegraphy. The fleet was intended for the Russo-Japanese War which began in February 1904 by an attack of the Japanese Fleet to Russian base in Port Arthur in the northern part of China. After installing the equipment, von Lepel was selected by the Russian Navy to familiarize Russian wireless operators with GDT technology during the Baltic Fleet's voyage to the island of Madagascar, which was not possible during assembly.

On 18 October 1904, the Baltic Fleet, commanded by Vice-Admiral Zinovii Rozhestvenskii (Semenoff, 1908), left St. Petersburg, circumnavigated the Danish town of Skagen to cross the English Channel towards Madagascar. In the North Sea near the so-called Dogger Bank Russian naval ships opened fire on British fishing boats on 21 October 1904, in which some fishermen died. This, of course, led to strong diplomatic reactions from Britain, while Russia tried to explain the attack on the fishing boats by mistaking them for Japanese torpedo boats. In this situation, on 11 November 1904, a telegram from the 23-year-old former lieutenant Egbert von Lepel, who was on board the "*Alexander III*" and was an eyewitness, was published in the "Berliner Lokal-Anzeiger", confirming statements made by Russia (Ein Augenzeuge, 1904, pp. 1–2). Excerpts from von Lepel's telegram were also partially published in some British newspapers. Based on Eugen Nesper's autobiography, von Lepel wrote a report on all his work for the Baltic Fleet to the German Kaiser Wilhelm II, who was very interested in von Lepel's statements. The director of the GDT, von Arco, who was unaware of von Lepel's report, became very angry when he found out about it and fired von Lepel for doing it alone. (Nesper, 1950, pp. 46–47).

It is clear that von Lepel's work at the GDT made him one of the few experts on the new technology of wireless telegraphy, and of course he wanted to use this knowledge even after he left the GDT, but there were few opportunities to do so. In 1905, GDT was the only company in Germany that developed the technical devices for wireless telephony, and the military and navy were among the main customers, excluding the first applications in civil shipping. So, if von Lepel was interested in developing wireless devices, and he probably already had some ideas about it, opening his own lab was his only option.

3 Egbert von Lepel and the Invention of the Spark-Gap Transmitter

After opening his laboratory, von Lepel developed a new concept for detecting electromagnetic waves. To do this, he used plate electrodes that were placed a short distance apart and between which there was a thin, poorly conducting layer. This layer changes its conductivity when hit by an electromagnetic wave. In August 1905 he filed a patent in Germany and then in 1906 a French patent. In 1908 this detector was described in a monograph on wireless telegraphy by Zacharias and Heinicke (Zacharias and Heinicke , 1908, pp. 70–71), but no other article or book mentions it. It was no exception that von Lepel's detector principle was not understood from a physical point of view, since neither was the case with the crystal detector invented at the same time. Therefore, he studied thin, poorly conducting layers, later on together with his former GDT colleague and electrochemist, Walther Burstyn (1877–1961), who was also dismissed by von Arco because of his arbitrariness. Egbert von Lepel mentioned in a later article that these studies were the starting point for the invention of his spark-gap transmitter.

In the description of the patent D.R.P. 232174 for the new transmitter principle in early 1907 (von Lepel, 1907), von Lepel emphasized that

> the invention is based on the fact that … it is possible to generate a charging process between metal electrodes that have a small distance compared to the area of the electrodes, which leads to sustained excitation of electromagnetic waves.

But even before von Lepel filed his patent, in January 1907 he invited von Arco to his lab to show him the invention, hoping it would be of interest to the GDT. Graf von Arco came with the head of the GDT laboratory, Ragnar Rendahl (1878–1929), and von Lepel demonstrated a first implementation of his invention, but they showed no increased interest. How-

ever, they asked von Lepel for further demonstrations in the GDT laboratory.

At the same time and independently of von Lepel's invention, Max Wien studied some physical effects related to Marconi's wireless telegraph system, which was greatly improved by Ferdinand Braun using the principle of resonance (Wien, 1906). Although the Braun-Marconi transmitter was a crucial step in terms of the transmitter's range, it quickly became clear that the interaction of coupled resonant circuits leads to oscillating energy between these circuits and with corresponding damping and represents a serious obstacle to increasing efficiency. In 1906, Wien returned to his earlier research and found that these energy oscillations could be suppressed by placing the spark generator electrodes close together. Wien published his results in September 1906 on the 78th "Assembly of German natural scientists and physicians" (Versammlung der Deutschen Naturforscher und Ärzte) in Stuttgart but only one question was asked. Wien's result was noted by the GDT because it was mentioned in a patent filed in 30 January 1907. However, its potential for a single pair of metal electrodes was not recognized by the GDT because, unlike von Lepel, it did not consider plate electrodes, although von Arco and Rendahl had recently visited von Lepel's laboratory. As late as early 1908, Rendahl published an article in which he was convinced that a transmitter with a mercury vapor spark gap was much better suited to realizing Wien's quenched sparks than other spark gaps (Rendahl, 1908). Only a short time later, the GDT realized that the production of a stable spark gap of this kind is hardly feasible (von Arco, 1909a).

In March 1908, Graf von Arco claimed in an article from 1909 in which he presented the new quenching spark-gap transmitter (von Arco, 1909a), the GDT tried to implement three different transmitter concepts based on the mercury vapor spark gap, the electric arc and the "Wien's method", which overcome the above-mentioned difficulty of the Braun-Marconi transmitter. However, Wien never suggested a method for the construction of a transmitter concept but only studied small distance electrodes without a description which kind of electrodes he used. "Then", von Arco wrote in his paper, "even greater success made us put everything else aside. After almost two years of effort, we finally succeeded in making Wien's process reliable and in using usable amounts of energy".

At this point of the article von Arco did not mentioned why they were successful but it follows a discussion about "quenched spark" and then Wien's results explained in detail. Already in a previous part of von Arco's paper Wien's result was assigned as

> crucial result, a German discovery, which, in terms of importance and scope, is on a par with the most important research results and inventions to date, but strangely enough, on the whole it has received relatively little attention, even here in Germany.

On the other hand, von Arco took up Rendahl's statement from 1908 that

> with the method of small spark gaps, the achievable amounts of energy are too small and the inconsistency of the oscillations is so great that Wien's method will probably never be put into practice

and pointed out,

> With Mr. Rendahl's approval, I would like to classify his statements at the time as a mistake.

There was also a reference to von Lepel's transmitter, but details were only found in the daily newspapers, von Arco said, although he was able to study von Lepel's first realization in the GDT lab.

4 Egbert von Lepel and the Marketing of his Transmitter Patents

Following the visit of Georg Graf von Arco and Ragnar Rendahl to von Lepel's laboratory at the beginning of January 1907, preliminary negotiations were held on the purchase of von Lepel's patents. In April 1907, however, these negotiations were broke off

> in account of his [von Lepel's] arrangement being then quite unserviceable

as von Arco later pointed out (von Arco, 1909b). Now, von Lepel was looking for other potential buyers who were interested in his patents. At that time in Germany there was only the C. Lorenz AG, which was engaged in wireless telegraphy and used Poulsen's patents to build an electric arc transmitter. Therefore, the only potential customer was the German army and he had good contacts with senior army officers. In order to be able to demonstrate his transmitter successfully, von Lepel worked on improving it and carried out further experiments (see Fig. 1).

Egbert von Lepel (von Lepel, 1909) contacted Poulsen, whose company had transmitter stations in Lynby near Copenhagen and Esbjerg on the Danish North Sea coast, for their experiments with Poulsen's electric arc transmitters. In September 1907, experiments over 260 km with an improved version of von Lepel's transmitter were successful which was reported in London's "The Daily Telegraph" (Wireless Telegraph, 1907) and even in some US newspapers. But von Lepel and Poulsen did not manage to conclude a contract for further cooperation such that von Lepel was looking for his own transmitter stations. Finally he used a fairly old station in Reinickendorf (at that time near Berlin) and another station in Braunschweig. These stations were used to demonstrate the wireless

> arrangement to the chief of Wireless Telegraph Section of the Prussian army.

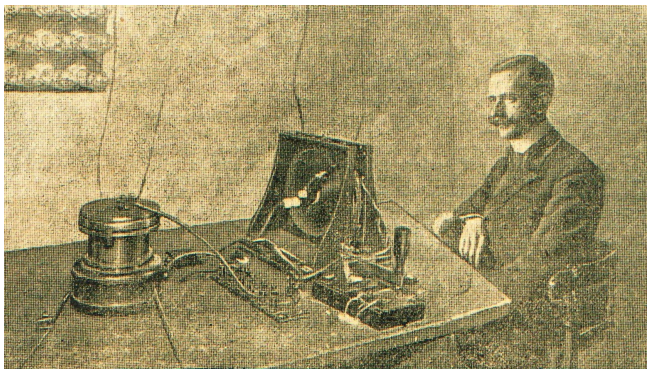

Figure 1. Egbert von Lepel and his wireless system. Deutsche Warte, Jg. 19, Nr. 32/33, 2 Februar 1908, 1. Beilage p. 5. (Staatsbibliothek zu Berlin, Germany).

A notice from Wolff's Telegraph Bureau dated 28 January 1908 (Wolff's Telegraphisches Bureau, 1908) was published by several German newspapers and also some European and non-European newspapers. Moreover, von Lepel carried out test over long distances between Reinickendorf and Norddeich, about 500 km. After the Poulsen ticker was replaced as a receiver by a detector developed by Walther Burstyn, the von Lepel-Burstyn system was independent of all other wireless systems. In Berlin the retired Major General Georg von Gayl (1850–1927) was another assistant in von Lepel's station in Reinickendorf.

The British magazine "The Electrician" reported in its 23 April 1909 issue that the German Army used the von Lepel system in the 1909 maneuvers (Wireless Telegraphy, 1909). However, the Wireless Telegraph Section of the Prussian army did not opt for the von Lepel-Burstyn system, but finally for the new Telefunken system developed by the GDT and therefore no other customer was available in Germany. Obviously, the only way was abroad and von Lepel was looking for customers for his wireless system in Great Britain.

In September 1908 von Lepel came to England and worked for three months under the supervision of the British Army's War Office at the former military telegraph station at Aldershot in Hampshire, which subsequently bought two of von Lepel's transmitters (Wireless Telegraphy, 1909). Because of this success, the Lepel Wireless Telegraph Syndicate Ltd. was formed on 6 March 1909 (National Archives London, 1906) with offices in London (Lepel Wireless Synd, 1909). This syndicate was known to have been bought from financier Ernest Goldsmid Abrahams, who already held the UK and Commonwealth patent rights of von Lepel and Burstyn. For the necessary experiments with the von Lepel-Burstyn system two transmitting stations were set up, one in Slough with a mast of 212 ft (65 m) and a receiving station in Twickenham with a mast of 50 ft (15 m). In 26 May 1909 officers from Admiralty (A.D.T Department) and the Royal Navy ship "H.M.S. *Vernon*" visited the Slough station and followed the successful experiments. Also von Lepel and Captain Simpson from the Syndicate were present during the visit.

Von Lepel's successes with his system were increasingly discussed in German and international daily newspapers, and his results were also discussed in electrotechnical journals. A new transmitter, developed by Burstyn and by von Lepel attracted particular attention, in which the frequency could be changed using a keyboard, but it was also suitable for playing music. In 4 June 1909 "The Daily News" reported about first experiments in its article "Visit to the Lepel Station at Twickham" where Basil Binyon (1885–1977) (Sanders, 2022), electrical engineer of the Lepel Wireless Syndicate who joined in 1909, explained some details of the station and demonstrated wireless telephony with von Lepel's transmitter (Wireless Telegraph, 1909, p. 9). This news was also reported in several other newspapers in the UK and US (e.g. Star Tribune News, 1909), also promisingly offering the ability to broadcast music through the keyboard. In 12 August 1910 the British newspaper "The South Bucks Standard" reported on experiments with this new transmitter, in which the British national anthem was transmitted from Slough's station to stations in Paris and Brussels ("Wireless" Experiments, 1910, p. 2). Again similar news was also found in other newspapers in the UK like "The Slough, Eton and Windsor Observer" ("Untappable Wireless", 1908, p. 6) from 20 August 1910, and in some US newspapers. As early as 11 August 1910, an article about this event appeared in the Berlin newspaper "Die Post" (Ein neues System, 1910).

Experiments were continued, but on 29 January 1911, "The Charlotte News", North Carolina, reported that "von Lepel was now in France pushing his patent that country" (Singing Spark are Successful, 1911). To this end, the Lepel Wireless Telegraph Syndicate of London in conjunction with the Compagnie Générale de Radiotéléografie of Paris are conducting joint experiments with von Lepel's transmitter. However, already in 12 May 1910 an extraordinary general meeting of the Lepel Wireless Syndicate, Ltd., had taken place where the following

> special resolutions were duly confirmed: 1. That the Company be wound up voluntarily. 2. The Baron Von Lepel and Mr. A. Holt be and they are hereby appointed Liquidators for the purposes of such winding up (National Archives London, 1910).

This certificate was included in the Lepel Wireless Syndicate files available at the British BT Archives in London. The reason for this dissolution is not known, but from then on Lepel's transmitter was marketed by the Compagnie Générale de Radiotéléografie.

But there were also potential customers outside of Europe for those the syndicate was dealing with in Jamaica, New Zealand and Australia and where they were in competition with wireless telegraph companies Marconi (UK) and GDT

(Germany). As early as 27 January 1910, Jamaica's newspaper "The Gleaner" reported on the establishment of a wireless station using a Lepel system built by the Lepel Wireless Syndicate (Our Wireless, 1910).

On 1 September 1913, the Anglo-French Wireless Company installed a von Lepel-Burstyn system in Nassau, Bahamas, and on 9 September 1913, Prince Albert of Monaco's yacht received a Lepel system from Compagnie Générale de Radiotéléografie which was also reported by some newspapers.

Von Lepel's transmitter and other inventions by him and Walther Burstyn were also discussed in electrotechnical journals and monographs, especially in international literature. In his 1910 book, "Wireless Telephones And How They Work", by British author James Erskine-Murray (Erskine-Murray, 1910), he describes von Lepel's wireless telephone as well suited. In the two US monographs from 1912, "A Treatise upon Wireless Telegraphy and Telephony" by Clay I. Hoppough (Hoppough, 1912) and "Experimental Wireless Stations" by Philip E. Edelman (Edelman, 1912), they each devoted an entire chapter to the description of Lepel's inventions. Also in Hugo Gernsback's electrotechnical US magazine "Modern Electrics" from February 1913 the transmitter with keyboard was explained in detail in the article "The Lepel Quenched Spark System" (Hyde, 1913, pp. 1133–1134). But in Germany, until the end of World War I, there were only two monographs on wireless technology that briefly mentioned the inventions of von Lepel and Burstyn: Jonathan Zenneck's monograph, "Leitfaden der Drahtlosen Telegraphie" (Guideline of Wireless Telegraphy) from 1909 (Zenneck , 1909) and Hans Rein's textbook "Lehrbuch der Drahtlosen Telegraphie" (Textbook of Wireless Telegraphy) of 1917 (Rein, 1917).

But already this limited number of references shows that von Lepel's inventions received much attention in the electrotechnical literature and in newspapers in the UK, in the USA and in some other countries, but not to a similar extent in Germany. This is very strange because he was well known in the relevant professional circles and personally well acquainted with a number of important German wireless pioneers. In particular, Eugen Nesper, Georg Graf von Arco and Hans Bredow knew Egbert von Lepel from their time together at the GDT, and at least Nesper and Bredow acknowledged von Lepel's inventions and its importance in their biographies, which were written around 1950. But even these colleagues from von Lepel have not reported everything that happened at that time and what is essential to understand the importance of Egbert von Lepel for the early days of wireless telegraphy and telephony. On the other hand, these biographies contain some remarks about von Lepel that show that he was an imaginative inventor (Bredow, 1954, 1956; Nesper, 1950). With the help of new archive documents, which were previously unknown in the context of the history of wireless technology, it was finally possible to get a more complete picture of the events of that time and of Egbert von Lepel as an important inventor.

5 The Patent Dispute between von Lepel and the GDT and its Consequences

While von Lepel's transmitter concept became known not only in the worldwide wireless technology community, but also in the general public through reports in the daily newspapers and the marketing of his transmitter system was quite successful, there were conflicts with the German wireless companies C. Lorenz AG and GDT. Before we go into more detail about the conflict with the GDT regarding the quenched spark-gap transmitter, a conflict with C. Lorenz AG regarding the transmitter with keyboard should be briefly discussed.

This case is also reminiscent of the case of the quenched spark-gap transmitter in early January 1907 because von Lepel asked his former GDT colleague and now with C. Lorenz AG, Eugen Nesper, whether he would be interested in seeing his new transmitter where the pitch of the impulses can be changed with a keyboard to better transmit signals in the presence of atmospheric disturbances. In fact, the company sent its wireless engineer Hans Rein to von Lepel's lab, who worked on a similar problem and found a solution to his key problem a few days after the visit, developing Lorenz's "Vieltonsystem" (multi-tone system). In the ensuing legal battle, Rein swore he had found the solution without knowledge of von Lepel's new transmitter (Nesper, 1950, pp. 62–63).

Apparently, Egbert von Lepel felt the need to share his new findings with former colleagues even without patent protection, which later got him into trouble. This applies in particular in connection with the dispute over the concept of the quenched spark-gap transmitter (Löschfunkensender) with the GDT and its director Graf von Arco. Already in the discussion of Graf von Arco's lecture on "Das neue Telefunken-System"(The new Telefunken system) at the 17th annual meeting of the VDE (Association of German Electrical Engineers) on 4 June 1909 (von Arco, 1909a), Walther Burstyn, also a former employee of the GDT, criticized von Arco for not adequately presenting von Lepel's contributions (Burstyn, 1909). In particular, he referred to von Lepel's patent DE232174 from 1907, which had still not been finally accepted by the Imperial Patent Office. The technical director of the GDT, von Arco, did not respond to Burstyn's detailed statements, but referred to his dispute with von Lepel in the British electrical engineering magazine "The Electrician". Graf von Arco explained to the applause of the session participants, he would be involved

> in a similar dispute there [The Electrician], which, however, will not lead to a clarification of authorship and the patent situation at this point either. I would therefore like to refrain entirely from going into the scientific or patent priority.

On 30 April 1909, Graf von Arco had published an article in "The Electrician" entitled "A New System of Wireless Telegraphy used by the Telefunken Company" in which he discussed some characteristics of the GDT's new wireless system, but without technical details (von Arco, 1909b), nor did he mention the contributions of von Lepels and his 1907 patent. Already in the following issue of "The Electrician" dated 7 May 1909, "The Lepel Wireless Synd. (LTD.)" General Manager, Adrian Simpson, published a statement on von Arco's article giving several details about the early development of of Lepel's system and of von Lepel's relationship to the GDT (Simpson, 1909). There follows a short note by the well-known James Erskine-Murray with additional comments in favor of the von Lepel system.

The issue of "The Electrician" dated 14 May 1909, the Lepel Wireless Syndicate published an article "The Lepel System of Wireless Telegraphy", which made no mention of the Telefunken system, probably also written by Adrian Simpson (The Lepel System, 1909). On 21 May 1909, von Arco responded in a letter to the editor of "The Electrician" with very personal attacks on Simpson and von Lepel (von Arco, 1909c). Von Arco initially pointed out that he had refrained from describing the method of the new "singing arc" system in his earlier article for patent reasons, but promised to give a detailed explanation at the upcoming VDE annual meeting in June. Then von Arco published some details of the contacts and preliminary negotiations between Lepel and himself taking place in early January 1907 and some internal statements by Captain Simpson about the Telefunken system, but in an incomplete manner. Finally, with regard to Wien's research results, he claims that

> The Telefunken arrangement is physically, if I may say so, the exact antithesis of the described in von Lepel's patent.

This was followed by the discussion between von Arco and Burstyn at the VDE annual conference.

On 18 June 1909, "The Electrician" published one of its very few articles by Egbert von Lepel (von Lepel, 1909). On 1 December 1909, he expressed himself again in a letter to the editors of the German Elektrotechnische Zeitschrift (ETZ) on the same facts, although the article was not printed until 1910 together with a reply from Graf von Arco dated 25 January 1910 in issue 5 of the ETZ (von Lepel, 1910).

In his June 1909 letter, von Lepel gave his view of the timing of inventions and contacts with the GDT to demonstrate that the claim made by von Arco in his May 1909 letter that he had no knowledge of the "German Specifications" of the Lepel-Burstyn system was incorrect. Then von Lepel outlined recent developments of his transmitter and ended with the following statements and a question he put directly to von Arco:

> I therefore think that, under the limitations which are necessary when publishing an article in the technical press, I have made it clear that the new Telefunken system is not an accidental but an intentional copy of my system, and I will, in conclusion ask Count Arco the question whether it is known to him that his own engineers designate the so-called now Telefunken system as "Die Lepelei".

Obviously, von Lepel's letter was a provocation for von Arco, who answered it on 9 August 1909 in his "The Electrician" article with the title "A last word on the new Telefunken system" (von Arco, 1909d), where he contradicted von Lepel's technical statements, summarized in three points. In the conclusion of this article von Arco added some personal words about von Lepel's claims that

> a great number of the German Telefunken applications … have been unlawfully derived.

But he also added:

> I, however, bind myself in "The Electrician" to make public the final judgments of the German Patent Office, and eventually of the German Courts of law as soon as they are given.

As mentioned above, in December 1909 and January 1910, respectively, von Lepel and von Arco made short notes in the German journal ETZ, which, however, did not contain any new aspects. It took another year for the German Imperial Patent Office to make a decision, which was promptly reported by well-known British newspaper "The Times" in a short note from 9 January 1911 (The Times News, 1911). The same note was published also by "The Electrician" on 13 January 1911 (Wireless Telegraph Notes, 1911):

> The Imperial Patent Office, after three years' litigation, has granted a patent for what is called the "singing spark" system of wireless telegraphy to Herr von Lepel ex-lieutenant of Uhlans, thereby recognizing him as the inventor.

The short note ended that

> The German companies will now be obliged to adopt the Lepel system.

This news probably hit GDT and von Arco like a bomb. In a letter to the editor of "The Electrician" on 3 February 1911 (von Arco, 1911), von Arco referred to his statement in "The Electrician" from August 1909 that he would comment on the result of the German Imperial Patent Office, if it were available, regardless of whether it was favorable or unfavorable for the GDT. Then he noted

> that the question of the Lepel patent is not yet finally decided, as the granting of the patent by the Patent Office is not a final decision in this sense. The Gesellschaft für Drahtlose Telegraphie m.b.H. has instituted proceedings in order to have this patent annulled. … Then only shall I be prepared to fulfill my promise to you.

He gave the impression that for him

> the question which was the principal point of the discussion – viz., whether the Telefunken Co. has illegally made use of the Lepel's invention.

Obviously this is not an issue for a patent office. However, it is also clear that an unfavorable outcome of the patent procedure would have serious financial consequences for GDT.

The editor of "The Electrician" reacted in the "Legal Intelligence" section (Legal Intelligence, 1911) with an article "Lepel and Telefunken Wireless Telegraph Patents", detailing the reasons why

> the Imperial German Patent Office has granted a patent to Baron von Lepel for what is called the "singing spark" system of wireless telegraphy, although the Gesellschaft für Drahtlose Telegraphy (Telefunken Co.) and C. Lorenz Akt.-Ges. of Berlin had opposed.

Since the GDT emphasized in their patent the importance of Wien's 1906 publication for their invention, the Patent Office commented on Wien's research results as follows:

> It is true that this action of small spark-gaps is mentioned [is meant: Wien 1906 paper] ... but only purely scientific questions are dealt with, no mention being made of the type or magnitude of the source of current nor the kind or dimension of the electrodes.

The second part of this article detailed the Comptroller-General's examination of the UK application for the GDT spark-gap transmitter patent. The procedure ended with the decision that the specifications of GDT in the patent had to be changed in two points; first point is essential:

> the preamble to the claims to read as follows: "I declare that I am aware of the patent specification of Egbert von Lepel No. 17.349 of 1908, dated Aug. 20, 1907, and I desire it to be understood that I lay no claim to anything described or claimed therein".

The trial before the Comptroller-General were conducted by representatives of both parties as well as Prof. Silvanus Thompson and Dr. James Erskine-Murray acted as experts, respectively.

As early as 2 February 1911, the magazine "Electrical World" in New York published a brief note on the results of the patent process in Germany regarding von Lepel and the GDT (Impact Excitation Patent, 1911). On the other hand, it was not until 16 February 1911 that the ETZ published a review of Lepel's 1909 article in "The Electrican" (Jentsch, 1911), including some criticisms, which Burstyn answered on 23 March 1911 (Burstyn, 1911).

As far as we know, the dispute between von Lepel and the GDT was only briefly mentioned again in the German electrotechnical journals. On 12 March 1912, a short note appeared in the ETZ entitled "Telefunken against v. Lepel" (Telefunken gegen v. Lepel, 1912):

> The action for annulment brought by the Gesellschaft für Drahtlose Telegraphie [GDT] against the v. Lepelsche Patent No. 232174 "Device for generating rapid oscillations from direct or alternating current" was rejected with costs.

However, a final statement by Graf von Arco on this result of the Imperial Patent Office, which he had promised to the editor of "The Electrician", was not published either in this journal or in the "Electrical World" until the beginning of World War I.

6 The von Lepel-Burstyn Patents and GDT's Secret Files

Although there were no further public announcements about the patent dispute between von Lepel and the GDT, the decision of the Imperial Patent Office led to consequences for the GDT. It is not known when the first negotiations between von Lepel and Burstyn and the GDT took place, but it seems clear that von Lepel did not negotiate until his return to Germany.

His last stay in the UK before World War I was in July 1914 where von Lepel was a guest of "A Wireless Dinner Party" which was given by Sir Henry Norman at his house in Cowley Street in London. "The Guardian" in its 16 July 1914 edition and other British newspapers reported on it (A Wireless Dinner Party, 1914). The invitation of the German wireless expert von Lepel and a representative of the company Telefunken together with other high-ranking British personalities from "Science and Practice of Wireless Telegraphy" had important consequences for Sir Norman in the British Parliament after the war. It does, however, illustrate the appreciation in which von Lepel was held in the UK at the time. With the beginning of the First World War, von Lepel returned to Germany and joined the army as an officer and was given the order to set up a new wireless station for the army in Königs Wusterhausen, where the station being given the identifier "LP" (Suckow, 2008, p. 11). In 17 February 1916, von Lepel became an appointed Captain (Rittmeister).

On 27 March 1916, a first contract was signed between the GDT and von Lepel, in which he sold the licenses to some wireless device patents from 1913 and 1914 to the GDT (Deutsches Technikmuseum, 1916). Apparently these patents are only of secondary importance for the GDT and therefore this license agreement could be interpreted as a first step towards an agreement on the key patent DE 232174. The contract, which began on 1 April 1916, guaranteed von Lepel 10 000 Marks per half year during the term up to 31 December 1920 and further fees for the licenses under certain conditions, a considerable sum (approx. EUR 25 000). It is interesting that the contract was signed by von Lepel and Hans

Bredow on the part of the GDT, although von Arco was the remaining director of the GDT and the former GDT commercial manager Bredow had been a voluntary sergeant in the army since autumn 1914.

On 8 June 1916, von Lepel was posted to the French front in occupied Rethel, where he took command of a wireless unit inspecting the German telegraph troops. This may be the reason why negotiations for von Lepel's key patent DE 232174 were not continued. Hans Bredow later often reported on his wireless telephony experiments, which he carried out in cooperation with the GDT employee and radio pioneer Alexander Meissner with a Telefunken tube transmitter at Rethel, and interpreted these events as an important step towards radio broadcasting ("Rundfunk") in Germany (Bredow, 1956, pp. 160–161). But it is almost unknown that von Lepel was the commander of Bredow's wireless unit in the 1st Army (A.O.K. 1) and put him in charge of the experiments on 26 April 1917 (Bredow, 1956, pp. 39–53, 161).

After the end of World War I, von Lepel and Burstyn probably pushed the GDT to continue negotiations on the still open question of the patent consequences of Lepel's patent DE 232174, on which the von Lepel-Burstyn system was also based. On 10 December 1919 von Lepel and Burstyn as well as Graf von Arco and Carl Schapira signed a contract in which GDT took over the licenses and paid 40 000 Marks (approx. EUR 100 000) once and then annually until 1925 16 000 Marks (approx. EUR 40 000) paid (Deutsches Technikmuseum, 1919). The license fees were divided by von Lepel and Burstyn as 60 % to 40 %. However, the most important parts of the contract for the GDT were that von Lepel and Burstyn

> expressly acknowledge that the assertion made by them previously that Telefunken has illegaly extracted the invention of Mr. v. Lepel is incorrect.

In § 7 of the contract the following is specified:

> The parties undertake not to communicate this contract to unauthorized persons.

That is why it is unknown to this day that the Imperial Patent Office the patent of the quenched spark-gap transmitter ("Löschfunkensender") awarded to von Lepel and not the GDT. Finally, on 26 September 1925, Lepel asked to cancel all contracts, which was accepted by the GDT.

Egbert von Lepel left Germany for the US, where he set up a new company, Lepel High Frequency Laboratories, Inc., in New York, which successfully built diathermy devices based on his quenched spark gap transmitter and other electromedical products. § 2 of the 1919 contract stated that this was expressly permitted. The company still exists today as Lepel – An Inductotherm Group Company, but Egbert von Lepel died in an accident in his laboratory in 1941. Whereas, US newspapers reported the dead of von Lepel, so in 8 April 1941 the New York Times with an article titled "Laboratory; Body of Egbert von Lepel, 60, Is Found in Gas-Filled Room" (Laboratory; Body of Egbert Von Lepel, 1941) and Hugo Gernsback's magazine "Radio & Televison" (Egbert von Lepel, 1941) pointed out that

> Students of radio history will remember von Lepel as one of the shining lights among the German radio geniuses back in the days of quenched spark gap and arcs.

No obituary for von Lepel appeared in German daily newspapers and electrical engineering magazines.

7 Conclusions

Using new archival material, this paper shows that one of the powerful German pioneers, Egbert von Lepel, was not adequately treated in the history of early wireless technology. Although von Lepel's achievements have been briefly mentioned in some historical articles and books, many details of this very interesting private inventor were not known. Using new historical sources, it was possible to reconstruct many details of von Lepel's biography, but this work focuses on his contributions to the quenched spark-gap transmitter. Finally, it is emphasized that von Lepel and his collaborator Walther Burstyn are among the early pioneers of wireless technology. A more detailed biographical article about Egbert von Lepel will be published elsewhere.

Data availability. No data sets were used in this article.

Competing interests. The contact author has declared that none of the authors has any competing interests.

Disclaimer. Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Special issue statement. This article is part of the special issue "Kleinheubacher Berichte 2022". It is a result of the Kleinheubacher Tagung 2022, Miltenberg, Germany, 27–29 September 2022.

Acknowledgements. I am very grateful to Christine S. Windheuser of The Archives Center of the National Museum of American History in Washington, who made many materials available in the United States about Egbert von Lepel and his company in New York. Furthermore, I thank the Bundesarchiv of the Bundesrepublik in Berlin, the archive of the Deutsches Technikmuseum in Berlin, and The National Archives in London which substantially supported my research in the history of early wireless technology.

Financial support. The publication of this article was funded by the open-access fund of Leibniz Universität Hannover.

Review statement. This paper was edited by Jens Anders and reviewed by two anonymous referees.

References

Berger, K.: Hallo! Hallo! Hier Eberswalde! – Die Versuchsstation für drahtlose Telegraphie in Eberswalde, Museum in der Adler-Apotheke, Eberswalde, Germany, 1998.

Bredow, H.: Verwendung der Funktelegraphie für das Pressewesen, Elektrotech. Z., 41, 75–77, 1920.

Bredow, H.: Vier Jahre deutscher Rundfunk, Reichsdruckerei, Berlin, Germany, 1927.

Bredow, H.: Im Banne der Ätherwellen, Band I: Der Daseinskampf des Deutschen Funks, Mundus-Verlag, Stuttgart, Germany, 1954.

Bredow, H.: Im Banne der Ätherwellen. Band II: Funk im ersten Weltkriege, Entstehung des Rundfunks, Mundus-Verlag, Stuttgart, Germany, 1956.

Brittain, J. E.: Alexanderson: Pioneer in American Electrical Engineering, Johns Hopkins University Press, Baltimore, USA, ISBN 0-8018-4228-X, 1992.

Burstyn, W.: Diskussion zum Vortrag von Graf Arco, Elektrotech. Z., 30, 786–787, 1909.

Burstyn, W.: Drahtlose Telegraphie System von Lepel, Elektrotech. Z., 32, p. 300, 1911.

Crisell, A.: An Introductory History of British Broadcasting, Routledge, London, UK, ISBN 9780415247924, 1997.

de Boer, P. A.: à Steringa Idzerda – De Pionier van de Radio-Omroep, De Muiderkring N.V., Bussum, the Netherlands, 1969.

de Forest, L. and Seibt, G.: Grand Opera by Wireless – Metropolitan Opera House in New York City (about a wireless telephony system developed by Lee de Forest and George Seibt), Telephony, 293–294, 5 March 1910.

Deutsches Technikmuseum: I.2.060 C – FA AEG-Telefunken, Geheimakte Lizenz- und Patentverträge, Egbert v. Lepel, Lizenzvertrag, GDT (H. Bredow) und E. v. Lepel, 10 pages and patents, Deutsches Technikmuseum, Historisches Archiv, Bestand, 4 pp., Berlin, Germany, 27 March 1916.

Deutsches Technikmuseum: I.2.060 C – FA AEG-Telefunken, Geheimakte Lizenz- und Patentverträge, Egbert v. Lepel, Lizenzvertrag, GDT (G. Graf v. Arco, C. Schapira) und E. v. Lepel and W. Burstyn, Deutsches Technikmuseum, Historisches Archiv, Bestand, 4 pp., Berlin, Germany, 10 December 1919.

Douglas, S.: Inventing American Broadcasting 1899–1922, Johns Hopkins University Press, Baltimore, USA, ISBN 0-8018-3387-6, 1987.

Edelman, P. E.: Experimental Wireless Stations, The author, Minneapolis, USA, 1912.

Erskine-Murray, J.: Wireless Telephones And How They Work, Crosby Lockwood and Son, London, UK, 1910.

Friedewald, M.: Die "Tönenden Funken": Geschichte eines frühen drahtlosen Kommunikationssystems 1905–1914, GNT-Verlag GmbH, Diepholz, Germany, ISBN 3-928186-38-8, 1999.

Fuchs, M.: Georg von Arco (1869–1940) – Ingenieur, Pazifist, Technischer Direktor von Telefunken, GNT-Verlag, Berlin – Diepholz, Germany, ISBN 3-928186-70-1, 2004.

Funk-Mitteilung: Der erste Rundfunksprecher in Europa – "Drahtlose Telephonie" in Königswusterhausen – Versuche seit 1920 – Das erste Rundfunkkonzert, Funk, 45, 371–372, 1927.

Goebel, G.: Nesper, Eugen Heinrich Josef, in: Männer der Funktechnik, edited by: von Weiher, S., VDE-Verlag GmbH, Berlin, Offenbach, Germany, 127–129, ISBN 3-8007-1314-4, 1983.

Hansert, A. and von Lepel, O. M.: Historisch-Genealogisches Handbuch der Familie v. Lepel (Lepell), Verlag Degener&Co., Inhaber Manfred Dreiss, Insingen, Germany, ISBN 978-3-7686-5201-8, 2008.

Hoppough, C. I.: A Treatise upon Wireless Telegraphy and Telephony, The author, Valparaiso, Ind., Chile, 1912.

Hyde, S. E.: The Lepel Quenched Spark System, in: Modern Electrics, vol. V, no. 11, New York, USA, 1913.

Jentsch, O.: Drahtlose Telegraphie, System v. Lepel, Elektrotech. Z., 32, 167–168, 1911.

Kintner, S. M.: Pittburgh's contribution to Radio, Proc. Inst. Radio Eng. (IRE), 20, 1849–1862, 1932.

Klöcker, E.: Das Funkwesen in Deutschland und die wirtschaftlicher Bedeutung des Rundfunks, Dissertation, Friedrich-Alexander-Universität Erlangen, Germany, 1926.

Lerg, W. B.: Die Entstehung des Rundfunks in Deutschland – Herkunft und Entwicklung eines publizistischen Mittels, Verlag Josef Knecht, Frankfurt/M., Germany, 1963.

Lerg, W. B.: Hans Bredow – Schwierigkeiten mit einem 100. Geburtstag, Mitteilung Studienkreis Rundfunk und Geschichte, 6, 127–129, 1994.

Mathis, W.: Drahtlos aus Eberswalde – Lorenz-Poulsen Lichtbogensender für den Rundfunk, in: Geschichte der elektrischen Kommunikation bis zum Smartphone, edited by: Titze, A., Klartext-Verlag, Essen, Germany, 85–110, ISBN 978-3-8375-2058-3, 2019.

Mathis, W. and Titze, A.: 100 Years of Wireless Telephony in Germany: Experimental Radio Transmission from Eberswalde and Königs Wusterhausen, Adv. Radio Sci., 19, 93–104, https://doi.org/10.5194/ars-19-93-2021, 2021.

Mehle, W.: Hier ist Königs Wusterhausen ... Eine Erinnerung an die Geburtsstätte des Deutschen Rundfunks, Arch. f. Deutsche Postschichte, 2, 25–32, 1955.

National Archives London: Declaration of Compliance for registration of The Lepel Wireless Syndicate, National Archives, London, UK, RC5363567, Limited, 6 March 1909.

National Archives London: Special Resolutions of The Lepel Wireless Syndicate, National Archives, London, UK, RC5363567, Limited, wind up, passed 10 April, confirmed 12 May 1910.

Nesper, E. (Ed.): Der Radio-Amateur, Vol. 1, Verlag von Julius Springer, Berlin, Germany, 1923a.

Nesper, E.: Der Radio-Amateur – "Broadcasting", Verlag von Julius Springer, Berlin, Germany, 1923b.

Nesper, E.: Ein Leben für den Funk – Wie der Rundfunk entstand, R. Oldenbourg Verlag, München, Germany, 1950.

Poulsen, V.: Method of Producing Alternating Currents with a High Number ov Vibrations, Patent US789449A, 1903.

Pungs, L.: Die neuere Entwicklung der drahtlosen Telephonie, Elektrotech. Z., 43, p. 1219, 1922.

Rein, H.: Lehrbuch der Drahtlosen Telegraphie, Verlag von Julius Springer, Berlin, Germany, 1917.

Rendahl, R.: Über Erzeugung schwachgedämpfter elektrischer Schwingungen, Phys. Zeitschr., 9, 203–205, 1908.

Ross, D.: Hans Bredow – Legende und Wirklichkeit – Betrachtungen zu einem Buch von Winfrid B. Lerg, Rundfunk und Fernsehen, 14, 150–168, 1966.

Sanders, I. L.: "Polar Radio Sets" – Basil Binyon, Castle Ridge Press, Morgan Hill, CA, USA, ISBN 978-0-578-97081-3, 2022.

Schröder, J.: Eine "geniale Erfindernatur", Heimatkurier, Beilage zum Nordkurier, Neubrandenburg, Germany, p. 27, 12 November 2007.

Seitz, F.: The Cosmic Inventor: Reginald Aubrey Fessenden (1866–1932), T. Am. Philos. Soc., New Series, 89, 1–77, 1999.

Semenoff, W.: Raßplata – Kriegstagebuch über die Blockade von Port Arthur und die Anreise der Flotte unter Rojestvensky, Ernst Siegfried Mittler und Sohn, Königliche Hofbuchhandlung, Berlin, Germany, 1908.

Simpson, A.: A New System of Wireless Telegraphy used by the Telefunken Company, The Electrician, vol. 63, No. 4, p. 142, 7 May 1909.

Star Tribune News: Music by Wireless to Become Possiblity – System Perfect Whereby Tunes May be Sent Hundreds of Miles – Baron Egbert Von Lepel Is the Inventor of the Very Simple Contrivance, Star Tibune, Minneapolis, Minnesota, USA, p. 21, 15 August 1909.

Sukow, R. (Ed.): ... Hier Königs Wusterhausen auf Welle 2700 ... – Beiträge zur Funkgeschichte in Königs Wursterhausen, 3rd edn., Druckerei Fröhlich, Bestensee, Germany, ISBN 978-3-86124-736-4, 2008.

Thurn, H.: Das Reichsfunknetz, Telefunken-Zeitung, IV. Jg., No. 20, 15–16, May 1920.

Thurn, H.: Der drahtlose Wirtsschafts-Rundspruchdienst, Elektrotech. Z., 42, 1355–1357, 1921.

Titze, A. and Mathis, W.: Kommunikation mit Strom – Telefon und Rundfunk, Museum Eberswalde, Stadt Eberswalde, Eberswalde, Germany, ISBN 978-3-9822404-2-8, 2020.

von Arco, G.: Das neue Telefunkensystem, Elektrotech. Z., 30, 535–567, 1909a.

von Arco, G.: A new system of wireless telegraphy used by the Telefunken Company, The Electrician, vol. 63, no. 6, 89–91, 30 April 1909b.

von Arco, G.: A new system of wireless telegraphy used by the Telefunken Company, The Electrician, vol. 63, no. 6, 228–229, 21 May 1909c.

von Arco, G.: A last word on the new "Telefunken" System, The Electrician, vol. 63, no. 17, 661–662, 6 August 1909d.

von Arco, G.: The Lepel Wireless Telegraph Patents, The Electrician, vol. 66, no. 17, p. 674, 3 February 1911.

von Lepel, E.: Einrichtung zur Erzeugung schneller elektrischer Schwingungen aus Gleich- oder Wechselstrom, Patentschrift, DE 232174, Berlin, Germany, 21 August 1907.

von Lepel, E.: The Lepel Wireless Telegraph System, The Electrician, vol. 63, no. 10, 374–376, 18 June 1909.

von Lepel, E.: Das neue Telefunkensystem, Elektrotech. Z., 31, p. 128, 1910.

Weichart, F.: In 14 Tagen – einen Sender für Berlin!, in: Rundfunk Jahrbuch 1930, edited by: Reichs-Rundfunk Gesellschaft, Union Deutsche Verlagsgesellschaft 1930, Berlin, Germany, 43–52, 1930.

Weichart, F.: Erinnerungen eines verdienten Funkpioniers aus seinem Leben und Wirken (überliefert und realisiert von Karl Neumann and presented by GFGF e.V.), Verlag Dr. Rüdiger Walz, Kelkheim, Germany, ISBN 3-9802576-6-5, 1997.

Wien, M.: Über die Intensität der beiden Schwingungen eines gekoppelten Senders, Phys. Zeitschr., 7, 871–872, 1906.

Wolff's Telegraphisches Bureau: Ein neues System für drahtlose Telegraphie mit kontinuierlichen Wellen, Wolff's Telegraphisches Bureau, 59. Jg., Nr. 425, Bundesarchiv, Berlin, Germany, R 4701/8877, 28 January 1908.

Zacharias, J. and Heinicke, H.: Praktisches Handbuch der Drahtlosen Telegraphy und Telephonie, A. Hartleben's Verlag, Wien, Austria, and Leipzig, Germany, 1908.

Zenneck, J.: Leitfaden der drahtlosen Telegraphie, Verlag Ferdinand Enke, Stuttgart, Germany, 1909.

A Wireless Dinner Party, The Guardian, London, UK, p. 8, 16 July 1914.

Der Friedensvertrag von Versailles [Versailles Peace Contract], Verlag von Reimar Hobbing, Berlin, Germany, 1925.

Ein Augenzeuge über den Zwischenfall in der Nordsee, Berliner Lokal-Anzeiger, 22. Jg., No. 532, Berlin, Germany, 11 November 1904.

Ein neues System für drahtlose Telegraphie, Die Post, Bundesarchiv, R 4701/8877, 11 August 1910.

Egbert von Lepel, Radio & Television, edited by: Gernsback, H., New York, USA, p. 94, June 1941.

Impact Excitation Patent, Electrical World, vol. 57, no. 5, p. 325, USA, 1911.

Laboratory; Body of Egbert Von Lepel, 60, Is Found in Gas-Filled Room, New York Times, New York, USA, p. 27, 8 April 1941.

Legal Intelligence – Lepel and Telefunken Wireless Telegraph Patents, The Electrician, vol. 66, 833–834, 3 March 1911.

Lepel Wireless Synd (LTD.), The Electrician, vol. 62, No. 22, p. 866, 12 March 1909.

Our Wireless – Establishment of the Station at Bowden, The Gleaner, Kingston, Jamaica, p. 4, 27 January 1910.

Singing Spark are Successful, The Charlotte News, 29 January, p. 2, Charlotte, USA, 1911.

Telefunken gegen v. Lepel, Elektrotech. Z., vol. 33, no. 11, p. 275, 14 March 1912.

The Lepel System of Wireless Telegraphy, The Electrician, vol. 63, no. 5, 174–175, 14 May 1909.

The Times News: Decision by the patent Office, January 8, 1911, The Times, p. 5, 9 January 1911.

"Untappable Wireless" – Some secrets of Baron von Lepel's new system of musical notes, The Slough, Eton and Windsor Observer, Slough etc., UK, 20 August 1910.

"Wireless" Experiments at Slough – Three countries in Touch, The South Bucks Standard, 12 August 1910.

Wireless Telegraph, Daily Telegraph, London, UK, 12 November 1907.

Wireless Telegraph – Visit to the Lepel Station at Twickesham, The Daily News, London, UK, 4 June 1909.

Wireless Telegraph Notes, The Electrician, vol. 66, 13 January 1911.

Wireless Telegraphy in the Territorial Force, The Electrician, vol. 63, No. 2, 52–53, 23 April 1909.