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A Brief History of Electricity, Magnetism, and Radio Science in Finland

Ari Sihvola

Abstract – This letter reviews historical milestones concerning the studies of electricity, magnetism, and radio science in Finland. Even if the first university on Finnish ground started as early as in 1640, the first dissertation concerning electricity was defended (by Gustav Polviander) in the year 1772. The discovery of electromagnetism in early 19th century inspired Johan Jacob Nervander to design a sensitive galvanometer, and the invention of wireless communication brought radio waves to Finland with the experiments by A.S. Popov. Since then, research and applications within the field have been expanding tremendously, resulting in a vibrant radio science community in Finland.

1. Introduction

Radio science rests on the foundations of electromagnetics, a scientific discipline that was quantitatively formulated in the late 19th century, and ultimately codified into the *Treatise on Electricity and Magnetism* by James Clerk Maxwell [1]. His groundbreaking achievement did not only set the scene of electrodynamics but also helped Albert Einstein to formulate his Special theory of relativity. Well-known is the anecdote which tells about Einstein's respect for Maxwell: *"I do not stand on the shoulders of Newton, but on the shoulders of Maxwell"*.

But also Maxwell stood on shoulders of others. Electric and magnetic phenomena were familiar to the mankind for millennia: Thales the ancient Greek philosopher spoke about the strange power of rubbed amber (in Greek language, amber reads indeed *"elektron")*, and magnetic effects of iron were reported long time ago by the Roman sages Pliny the Elder [2] and Titus Lucretius Carus [3].

From antiquity, centuries passed, and the understanding of electricity and magnetism grew. Petrus Peregrinus in late Middle Ages wrote his Epistola [4] about magnetic poles of the lodestone and Earth magnetism. Gilbert's *De Magnete* [5] from the year 1600 was a comprehensive discussion on the topic on not only magnetism but also on static electricity.

The 18th century saw the beginnings of quantitative electrostatics through the works of Charles Augustin de Coulomb, the electric battery was created by Alessandro Volta in 1800, and finally electromagnetism was discovered by Hans Christian Ørsted in 1820 with his observation of the magnetic force of an electric current. The complementary effect, generating electricity from magnetism, in 1831, was the result of Michael Faraday's investigations. But electromagnetic theory was not yet fully developed: the concept of displacement current was essential in a consistent set of electrodynamic equations. And this was formulated by Maxwell in his articles in 1860's.

Parallel to these developments, scientific studies about electricity and magnetism were cultivated also in Finland. In the following, I will raise certain salient discoveries in the history of the intellectual developments in Finland in the fields of electromagnetism and radio science.

2. 17th century

Finland was by no means the center of civilization of Europe in the past centuries. Nevertheless, already in the 14th century, several Finnish young men were sent to search for education in European universities. But it was not until 1640 when the first university was founded in what is the present-day Finland. The decree by Queen Christina (reigning 1632–1654) established the Royal Academy of Turku (Åbo). The mission was to educate priests, medical doctors, military officers, and administrators to serve the crown (Finland was the Eastern part of the Sweden for centuries, including the period 1611–1721 when Sweden was a superpower in Europe). The first doctoral dissertation in Finland (and the first printed book in Finland, for that matter) was *Discursus politicus de prudentia* (A political discussion on prudence) [6] by Mikael Wexonius from the year 1641 (the thesis was defended by his student Enevaldus Svenonius Pontanus). However, natural sciences were not in the focus of the research and education during this century. Furthermore, the Great Northern War and in particular the devastating Great Wrath (1713–1721) closed the activities of the university for several years.

3. 18th century

The age in 1700's has been called the century of Enlightenment, which also flourished in Sweden and Finland. Like today, the strategic goals of the university focused on applications, the research based on reason should serve the public good, and fields like plant breeding and agriculture were important. Investigations of physical and chemical phenomena received attention. Despite the fact that electricity of that time was not considered a hot topic in the scientific community, there was some interest into it also in distant Finland.

The first doctoral thesis defense on electrical phenomena in Finland took place on 6 May, 1772, in the Royal Academy in Turku (Figure 1). Gustav Polviander defended the understanding of static electricity in the thesis with title *Hypotheses De Caussa Electricitatis* (Hypotheses on the foundations of electricity). In this publication [7] one can find references to many of the pioneers and central actors the field: William Gilbert, Stephen Gray, Charles Dufay, Benjamin Franklin, Samuel Klingenstierna, and Johan Albrecht Euler, among others.

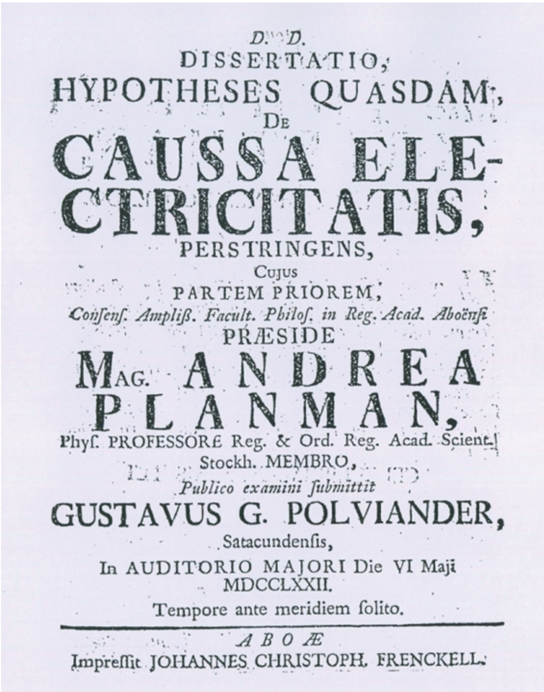

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Figure 1: The first doctoral thesis on electricity in Finland. Defended by *"Gustav G. Polviander, from Satakunta, in the Main Hall of the University, at the usual time a.m., on May 6, 1772."*

4. 19th century

The Napoleonic wars affected strongly the political landscape in Scandinavia. From the Finnish perspective, the change was radical: in 1809, Finland was ceded from the Kingdom of Sweden to become an autonomous grand duchy of the Russian Empire. Furthermore, after a catastrophic fire in Turku in 1827, the university was moved to the new capital, Helsinki. The Royal Academy received a new name "Imperial Alexander University", named after the Emperor Alexander I (reigning 1801–1825) due to his generous financial support to the institute.

The early 19th century saw the birth of electromagnetism. This did not happen unnoticed in Finland. One of the young graduates of the new university, Johan Jacob Nervander (1805–1848), entered with full force into studying the magnetic effect of galvanic electric current and accurate measurement of the Earth's magnetic field [8]. Nervander (Figure 2) had good contacts both with the leading European scientists and also with the political administration in the imperial capital St. Petersburg. Hence he managed to organize the building of a magnetic observatory in Helsinki. This provided decade-long measurements and valuable data about the temporal variations of the geomagnetic flux over different time scales [9].

Figure 2: Johan Jacob Nervander 1805–1848. (lithograph by Frans Oskar Liewendahl, based on a painting by Carl Petter Mazér (1837), in the Antell and Wadström collections, Museovirasto. (Source: Finnish Heritage Agency; used under Creative Commons Attribution 4.0 International Public License.)

One of the most important Nervander's contributions to electroscience is the so-called "tangent-bussol". This instrument is a galvanometer with which the magnitude of electric current could be quantified. Nervander presented his instrument to the French Academy of Sciences in its meeting in Paris on 3 March 1834 [10]. It is worth noting that the concept of electric current became in use only later, once the work *Die galvanische Kette* by Georg Simon Ohm gained acceptance. Although galvanometer prototypes had been presented soon after Ørsted's discovery by J.S.C. Schweigger, L. Nobili, and

C. Pouillet, it is impossible to understate the innovativeness of Nervander's tangent-bussol: its extreme sensitivity derived much from the structural design where the current-carrying coils are wound in a manner which emulate a continuous surface current around the box containing a long magnetic needle.

5. Towards 20th century

Even if Maxwell's electrodynamic theory was presented in early 1860's, it took a long time before the exploitation of radio waves to various purposes was possible. Firstly, the empirical confirmation that electromagnetic waves behave like light happened only in late 1880's with the experiments in Karlsruhe by Heinrich Hertz. Moreover, Hertz did not see the possibilities of his waves being able to carry information. Wireless communications were invented in the last years of the century, by Guglielmo Marconi (1874–1937) in Italy and Alexander S. Popov (1859–1906) in Russia.

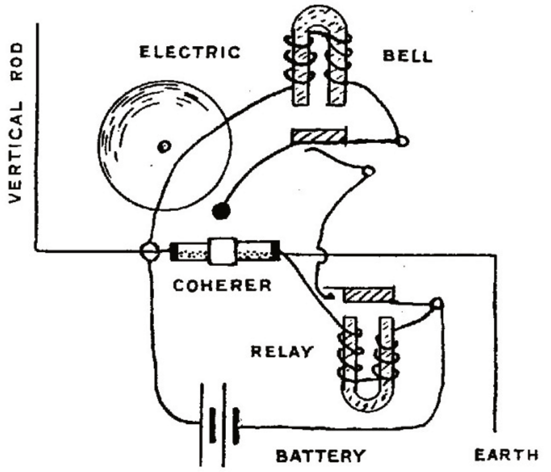

Figure 3: Popov's apparatus for the reception of radio disturbances. Note the essential circuit element, *coherer*, capable of changing itself into a conducting state when excited by an electric pulse from the "antenna". The resulting current triggers electromagnets with the effect of a bell sound followed by a knock on the coherer to bring it back into an insulating state.

Indeed, one thread of the history of radio science to Finland is connected to Popov. He had demonstrated the transmission on information by radio waves in 1896 (Figure 3), but already some years later he was able make use of his apparatus in a hostile marine environment. In 1899, the Russian battleship "General-Admiral Apraksin" had run aground in the Gulf of Finland. Popov was called to establish a communication link to assist in the rescue operation. He built a 40-km-long radio link from the coastal town of Kotka (in present-day Finland) to the Hogland island where Apraksin was shipwrecked.

In the domain of electromagnetic modeling of materials, a fundamental scientific discovery was made by Karl Ferdinand Lindman [11, 12]. In 1914 in Helsinki, he showed the effect of rotation of the polarization plane of a radio wave as it propagates through handed media (Figure 4). In today's electromagnetic terminology, objects that are different from their mirror image are called *chiral*, and hence one could say that Lindman was experimenting with chiral media. Lindman immersed copper helices (all of the same handedness) into cotton balls in random orientation, and shone a linearly polarized radio wave through this ensemble, observing the rotation of the polarization. For propagation of visible light, it was known from the studies by Biot and Pasteur (already in the first half of the 19th century) that parity-breaking liquids, like tartaric acids, display this type of rotatory power, so-called optical activity. Instead of such natural organic materials, Lindman fabricated artificial chiral media, effective in the microwave region.

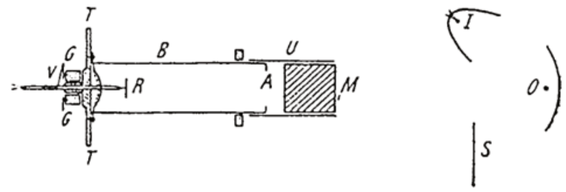

Figure 4: Lindman's experimental setup. His artificial chiral medium sample (cotton-packed copper spirals) resides in box *M*, through which the wave propagates into the hollow tube *B*. The transmitting oscillator *O* is located in front of a reflector. The receiver dipole *R* can be rotated with the stick *T* to find the angle with which the received wave is maximum. Reproduced from [11], with permission.

The use of radio waves for communications started to expand in the beginning of the century, all over the world. Public-service radio broadcasting saw its beginnings in Finland in 1926, and commercial activities within radio technologies and electronics started to expand. Also in academia, radio engineering was considered important: in 1923, a chair in radio engineering was established in the Helsinki University of Technology. It took, however, some time before the first doctoral degrees were granted in Finland. The first one was gained by Mr. Jouko Pohjanpalo in 1941. The topic of his his thesis was "A method to improve the efficiency of a modulated radio transmitter". It was written in Finnish. The next ones were already in English: Pentti Mattila ("Detection of weak periodic signals form noise," 1955) and Martti Tiuri ("Investigations of radio reflections from satelliteproduced ion trails using 100 Mc CW radar", 1960).

6. 21st century

The applications of electromagnetics and radio science penetrate everywhere in today's society. New innovations make use of multiple technologies, which makes it difficult to define the boundaries of radio science in the present century. One possibility to answer the question *What is radio science?* is to follow the classification of the International Union of Radio Science (URSI).

The ten Commissions (labeled from A to K) of URSI are (A) Electromagnetic Metrology, (B) Fields and waves, (C) Radiocommunication Systems and Signal Processing, (D) Electronics and Photonics, (E) Electromagnetic Environment and Interference, (F) Wave Propagation and Remote Sensing, (G) Ionospheric Radio and Propagation, (H) Waves in Plasmas, (J) Radio Astronomy, and (K) Electromagnetics in Biology and Medicine.

The union is already over hundred years old: URSI was founded soon after the First World War. Finland, despite being a small nation, joined the union early: the Finnish national member committee was formed in 1953 [13]. Finnish radioscientists have had a strong engagement within the activities of URSI over decades. Examples of URSI commissions into which Finnish research has contributed are B (fundamental electromagnetics research including wave-material interaction modeling and metamaterials), F (remote sensing of snow, ice, sea, and forests), G and H (magnetospheric and space weather studies, in particular by contributing to the operations of the European Incoherent Scatter Scientific Association EISCAT), and J (radioastronomical research on celestial objects all the way from the nearby solar system to distant galaxies, quasars, and other deep-sky objects).

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