Oliver Lodge: *Almost* the Father of Radio

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Sir Oliver Lodge
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By the year 1887, the 36-year-old Oliver Lodge was already regarded in Great Britain as a highly accomplished scientist. A professor of physics at the newly-established University College in Liverpool, he was known for his brilliant scientific mind and ability to explain complex scientific principles in a manner that could be understood by virtually anyone. In 1887, the Royal Society of Arts asked Lodge to prepare a series of lectures, to be given the following year, concerning how buildings might best be protected from lightning damage.[1]

The designers of the lightning protection systems of that time assumed that lightning was a continuous direct current discharge. They believed that protection from lightning could be obtained by placing copper rods above the buildings and connecting them to the earth by means of heavy copper grounding cables with a very low dc resistance.[2]

The lightning protection "experts" could not understand why lightning discharges frequently ignored the copper conductors and chose what seemed to be higher resistance "alternate paths" to ground.[3] This often resulted in great damage being done to the buildings. Such failures of the lightning protection systems was typically blamed poor ground connections.[4]

Lodge had had an interest in learning more about the subject for several years.[5] He now planned to conduct a series of experiments on electrical discharges prior to giving the lectures. The scientist intended to learn why lightning often did not follow the low-resistance path provided by the copper conductors.[6] He immediately began a series of experiments to learn more about lightning protection.

These laboratory investigations proved to be extremely important. They would contribute substantially to the development of wireless telegraphy and establish Lodge's world-wide reputation as an outstanding scientist.

In addition to demonstrating the effects of inductance in circuits with time-varying currents, the experiments ultimately resulted in Lodge establishing the existence of electromagnetic waves independently of, but virtually simultaneously with, the German scientist Heinrich Hertz. Lodge also discovered the phenomenon of electrical resonance and found that the "coherer" effect provided a very useful means for detecting the presence of electromagnetic waves.[7]

It was commonly known in 1887 that a lightning discharge is produced when the accumulation of electric charge in a cloud causes the potential difference between that cloud and the earth to increase until the intervening air breaks down electrically and becomes a conductor. Lodge visualized this as being much the same process as when the voltage across a capacitor increases until the breakdown of the dielectric occurs.[8] It also was well known that the discharge of a Leyden jar (capacitor) produces an oscillatory current rather than a direct current.[9] Oliver Lodge erroneously believed, therefore, that a lightning discharge also is oscillatory.[2]

The physicist decided to perform some preliminary "alternate path" experiments to attempt to confirm his theories prior to giving his first lecture on lightning in March of 1888. He used Leyden jar discharges to simulate lightning. The jars were usually charged using a Voss machine that generated static electricity through friction. One of the experimental arrangements used by Oliver Lodge is shown as Figure 1.[4,6]

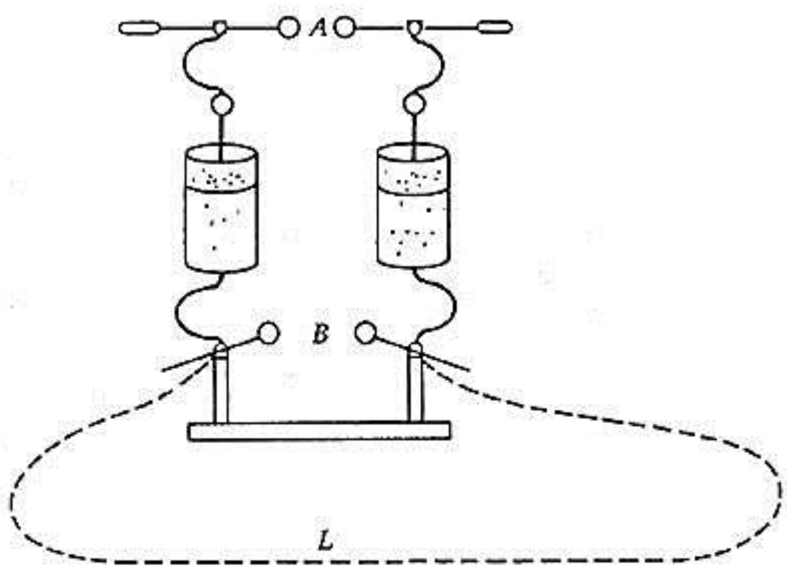

Fig. 1. Lodge's "alternate path" experiments demonstrated the effect of inductance in lightning protection circuits.

The Voss machine was connected to the terminals, A. These, in turn, were connected to the inner conducting surfaces of two Leyden jars. The outer conducting surfaces of the jars were connected to an adjustable spark gap, B. A long loop of very low resistance copper wire, L, was connected across this spark gap. The wire Lodge first used was approximately 12 meters in length but had a resistance of only 0.025 ohm. [4,6] It wire closely simulated the characteristics of the conductors normally connected to lightning rods.

The electrical charge stored in the Leyden jars could flow either through the very low dc resistance path provided by the loop of wire or it could flow across the very high resistance path through the air between the spark-gap terminals at B. It would seem that the obvious path for the charge to follow would be through the low resistance wire loop. Surprisingly, Lodge was able to produce very large sparks across the spark-gap, B, even though the dc resistance of the wire across the gap was only a fraction of an ohm.[4]

When Lodge gave his first lecture on lightning to the Royal Society of Arts, he argued that since (as he believed) lightning discharges have a very high oscillatory frequency, it is necessary to take inductive reactance effects into account when predicting which path the discharges will follow. Inductance was not a very well understood or accepted concept in those days.[6]

Michael Faraday in England and Joseph Henry in the United States, independently but almost concurrently, had observed some effects of inductance almost sixty years earlier. Sir William Thomson (Lord Kelvin) in 1853 had recognized the influence which inductance (Thomson called it "electro-dynamic capacity") has in causing the discharge of a Leyden jar to be oscillatory.[9]

Oliver Heaviside later demonstrated the importance of inductive effects in the transmission of signals along long telegraph lines and undersea telegraph cables. The concept of inductance, however, did not receive general acceptance or understanding until Sir William Thomson (Lord Kelvin) publicly endorsed Heaviside's inductance theories in 1889. Lodge's lectures on lightning, however, occurred prior to Thomson's endorsement.[2]

Lodge maintained that, at the frequencies involved in the oscillatory lightning discharge, the inductance of the conducting cables resulted in a very high opposition to current flow. Therefore, the alternate path actually followed by a lightning discharge did indeed exhibit the lowest total opposition or impedance to the current flow even if its dc resistance was not the lowest.[6]

Those in attendance who did not subscribe to Lodge's inductance theories were quick to question the accuracy of simulating lightning with Leyden jar discharges. Particularly questionable, they argued, was the idea that a lightning discharge is oscillatory.[1]

Years later, Lodge realized that lightning is not an oscillatory discharge but is actually a rapidly pulsating unidirectional (dc) discharge.[2] However, the effects of the inductive reactance on the flow of these pulsating lightning currents is the same as Lodge predicted for oscillatory currents.[6]

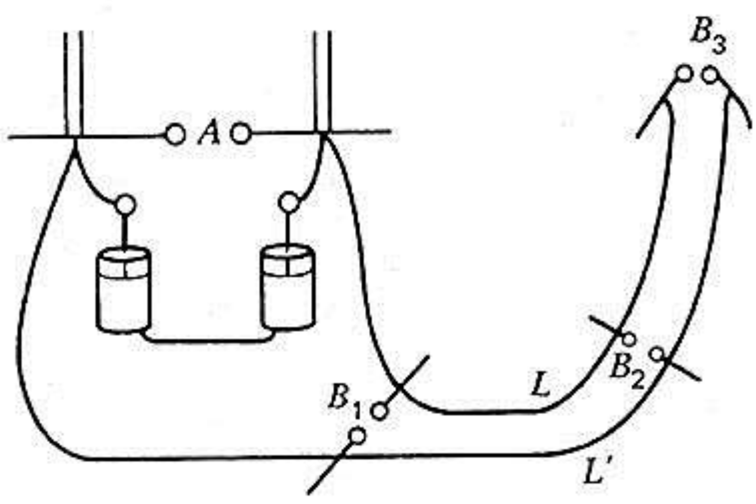

Fig. 2. While experimenting with this circuit, Oliver Lodge verified that the electromagnetic waves predicted by Maxwell do indeed exist.

The issue could not be resolved satisfactorily at the March lectures, and the critics wanted more convincing experiments to be performed. Further discussions on lightning were scheduled for the September 1888 meeting of the British Association to be held at Bath, England.[1]

Oliver Lodge continued his "alternate path" experiments during the spring and summer of 1888 with the purpose of investigating the behavior of the electrical oscillations produced by the Leyden jar discharges. He now replaced the loop of wire he had been using with a pair of long wires, each approximately 29 meters in length (Figure 2). The wires, L and L', were terminated in spark-gaps.[4,6] He found that the Leyden jars discharged in the usual manner at spark-gap A, but that a simultaneous spark was produced at spark gaps B1, B2, or B3.

Oscillatory currents were produced in the part of the circuit consisting of the Leyden jars and the spark-gap at A. The capacitance of the jars together with the inductance of the spark-gap wires at A determined the frequency of the oscillations.[4] Every time a spark occurred at A, however, Lodge found that a longer spark occurred at B1, B2, or B3. The spark at B3 always was the longest.

The electrical waves produced by the oscillations at A traveled along the wires and were reflected at the far ends. Lodge knew that the longer spark at B3 was due to what he called the "recoil impulse" or "recoil kick" at the end of the wires where the waves were reflected.[4] At spark gap B3 both the incident wave and the reflected wave had their maximum values and were in phase. This produced a voltage twice as large as the voltage at spark gap A.

More importantly, Lodge determined that the discharge at B3 was the most intense when the lengths of the two wires L and L' were one-half wavelength (or an integral multiple of one-half wavelength) for the oscillations produced.[4,8] Under these conditions, a maximum coupling of the oscillations produced at A was occurring in the wires. Oliver Lodge had discovered electrical resonance (or "syntony" as he later would call it[6]) between the two parts of the circuit.[4,8]

In addition, the scientist was able to demonstrate that standing waves existed along the wires. In a darkened room, he observed a visible glow along the wires at one-half wavelength intervals corresponding to the voltage peaks. He also performed a number of other experiments concerning the characteristics of discharging Leyden jars during that spring and summer of 1888.[11]

Oliver Lodge clearly knew that he had produced and detected the electromagnetic waves predicted some twenty-four years earlier by James Clerk Maxwell.[3] Before he presented these observations as part of the findings in his study of lightning conductors, however, Lodge went on vacation in that summer of 1888. It was while on vacation that Lodge read of Hertz's similar work with electromagnetic waves.[6,10] Lodge then added a postscript to his own paper acknowledging Hertz's work in an extremely positive way. He concluded the postscript by saying: "The whole subject of electrical radiation seems working itself out splendidly."[8]

Lodge presented his findings to the British Association meeting in Bath in September of 1888. The well known theoretician, G. F. FitzGerald, who reported on the results Hertz recently had published, chaired the meeting. Interestingly enough, FitzGerald had told Lodge in 1878 that it never would be possible for anyone to produce the electromagnetic waves predicted by James Clerk Maxwell. By 1882, however, FitzGerald had corrected his erroneous belief.[12] The following year, FitzGerald suggested that electromagnetic waves might be produced by discharging a capacitor through a very small resistance.[3]

Those in attendance and, later, other knowledgeable people, recognized that Lodge's findings were equivalent to those of Hertz and had been arrived at independently of, and virtually simultaneously with, Hertz's.[3,6] Heinrich Hertz, however, would always receive the world's principal acclaim and recognition because his work was published slightly before that of Lodge.

The electromagnetic waves generated by Hertz were radiated into space whereas those generated by Lodge were guided by wires. Consequently, the work of each man helped confirm the validity of what the other had done. Lodge and Hertz corresponded and exchanged scientific papers. They always maintained great respect and regard for each other as scientists and as human beings.[3] Lodge never resented the fact that Hertz's work received greater acclaim.[6] When Hertz died in 1894, Lodge wrote a magnificent tribute to his achievements.[13]

In 1894, Lodge discovered that a nonconducting tube containing metal filings (Figure 3) could be used to detect the presence of electromagnetic waves. His findings were based on an observation made in 1890 by Edouard Branly (1846-1940). Branly had discovered that the resistance measured across the ends of a such a tube normally was very high. However, if an electromagnetic wave was generated nearby, the metal particles became fused together and the resistance dropped to a low value. The resistance remained low until the tube was tapped and the fused particles returned to their original, separated condition.[14]

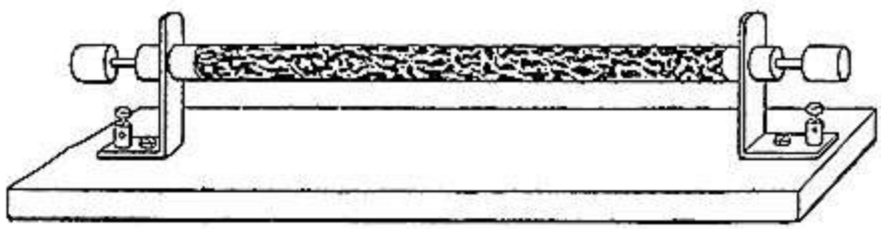

Fig. 3. Lodge's early "metal filings coherer" used to detect electromagnetic waves.

Earlier, Lodge had observed the same fusing effect between metal spheres in light contact with each other when an electromagnetic wave was produced. He called the fusing of the metal produced by the electromagnetic wave, the "coherer effect." Similarly, he called any detector of electromagnetic waves based on this effect, a "coherer." He quickly realized that the "filings tube coherer" represented the most convenient form for utilizing the coherer effect to detect electromagnetic waves.[15]

Perhaps Lodge's most important improvements to the filings tube coherer were the evacuation of the air from the tube and the development of an automatic "tapping back" device which utilised a rotating spoke wheel driven by a clockwork mechanism. The mechanical impulses provided by the tapping back device restored the filings tube coherer to its non-conducting state at regular intervals, independent of the detection of electromagnetic waves. This filings tube coherer detector was considerably more sensitive than was the simple wire loop "resonator" with a spark gap that Heinrich Hertz had used as the detector of electromagnetic waves in his experiments. It also was more convenient to use than was the metal-sphere coherer detector Lodge had previously developed.[15]

Lodge used his improved filings tube coherer, together with a Hertzian wave oscillator, as part of a demonstration for a commemorative lecture entitled "The Work of Hertz" given in London at a meeting of the Royal Institution in June of 1894. A sensitive mirror galvanometer was connected to the coherer so that the detection of the electromagnetic waves was visible to the audience in the form of a moving beam of light.[6,16] Later that same month, Lodge used a small portable receiver based on similar equipment to demonstrate the detection of electromagnetic waves at the annual "Ladies' Conversazione" of the Royal Society in London.[6,17]

He also demonstrated essentially the same apparatus at a meeting of the British Association held at Oxford in August of 1894. In that demonstration, however, he replaced the mirror galvanometer with a more sensitive marine galvanometer of the type normally used for the detection of submarine cable telegraphy signals. Lodge's source of electromagnetic waves, located in another building some 55 meters away, consisted of a Hertzian oscillator energized by an induction coil. A telegraph key connected to the primary winding of the induction coil was used by Lodge's assistant to send both long and short duration trains of waves, corresponding somewhat to Morse code dots and dashes.[6] Those in attendance witnessed Lodge's receiving equipment detecting electromagnetic waves that had traveled the 55 meter distance.

Lodge clearly had all the necessary elements of an elementary wireless telegraphy system. While it could be argued successfully that Lodge did indeed achieve signaling of a sort in all three of these demonstrations, there is no indication that the sending of any true messages was accomplished or even attempted with this apparatus. It was not his intent to do so. Oliver Lodge never considered using his equipment for communicating, although the idea of wireless telegraphy had been suggested two years earlier by William Crookes.[18]

The first two demonstrations were performed simply to show that electromagnetic waves can be generated and detected. The purpose of Lodge's demonstration at Oxford was to propose that perhaps there exists an analogy between the way a coherer responds to electromagnetic waves and the way the eye responds to light.[6]

Oliver Lodge later admitted that, at the time, he had not seen any advantage in using the relatively difficult process of telegraphing across space without wires to replace the well developed and comparatively easy process of telegraphing with the use of connecting wires.

He, like virtually all of his contemporaries, believed at the time that electromagnetic waves travel only in straight lines as does light. (Maxwell, after all, had shown that light is nothing more than electromagnetic waves with very short wavelengths.) Consequently, Lodge assumed that the maximum possible range attainable using wireless signaling would be very limited. These reasons help to explain why, in Lodge's own words, ". . . stupidly enough no attempt was made to apply any but the feeblest power so as to test how far the disturbance could really be detected."[19] As a result, Lodge was one of several electrical experimenters who, had they recognized what they had in their hands, might have earned the principal credit for the development of wireless telegraphy.

In all fairness, however, one should never think that Lodge was lacking in either insight or in astuteness. His exceptional perceptiveness and keenness of mind when conducting experiments had been demonstrated time and time again. But he was first and foremost a scientist and teacher, more concerned with theory than

commercial applications.[6]
While Oliver Lodge is remembered for numerous significant scientific achievements, including his contributions to the development of wireless telegraphy, it might be said that he let "the two big ones" slip through his fingers. Had he proceeded with his alternate path experiments a little more rapidly, Lodge might be the one whom we today credit with having experimentally verified Maxwell's predictions. Similarly, if Lodge had realized the potential of wireless communication, Marconi might have had to share with him the unofficial but commonly used title "Father of Radio."
Those wishing to read about other aspects of Oliver Lodge's life are referred to the author's earlier, less specialized article.[20]

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