BY ERIC P. WENAAS

RESEARCHING THE REAL INVENTOR OF RADIO TELEGRAPHY

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The history of wireless communication is replete with stories of important inventions and the inventors who had priority for discovering them. There have been many controversies about priorities of invention over the years, but none so great as who has priority in the invention of radio. Priority depends upon the way the question is posed, and historically the question of who invented radio has often been posed as "Who was the first to demonstrate transmission and reception of intelligible signals using Hertzian waves?" The phrase "intelligible signals" in this context means signals conveying intelligence such as with Morse code—certainly more than conveying simple signals indicating a "Yes" or "No." Without the caveat of conveying intelligence, the first one to transmit and receive Hertzian waves for any purpose could be considered the inventor of radio.

While there have been a number of candidates for priority in sending and receiving intelligible signals, the focus of this article is on the controversy over the priority of Sir Oliver Lodge versus Guglielmo Marconi. This has been contested ever since Marconi's English patent for his method of wireless telegraphy was first published on July 2, 1897. The controversy continues to this day with strong arguments having been made in behalf of both. The lack of consensus is evident in recently published books, some of which have awarded priority to Marconi while others have awarded priority to Lodge.[i]

Recently discovered in the course of another research project were two previously unchronicled documents that have a direct bearing on this issue. In fact, they should settle it once and for all. One was published in 1894 and the other in 1907. Both contain new first-hand accounts by Oliver Lodge of his Oxford telegraphic demonstration of August,1894, around which the entire argument of priority revolves. Lodge's new accounts of this demonstration will be compared and contrasted to his previously chronicled claims for telegraphy there. But before that, some background material will be presented to provide the basic parameters of the controversy.

Background

For most of the 20th century, Marconi was accorded priority as the first to transmit telegraphic messages by Hertzian waves. Perhaps the most significant figure to accord Marconi's priority was Judge William K. Townsend, who in upholding the validity of Marconi's original patent in his decision rendered on April 11, 1905 in Marconi v. de Forest, stated:

It would seem, therefore, to be a sufficient answer to the attempts to belittle Marconi's great invention that, with the whole scientific world awakened by the disclosures of Hertz in 1887 to the new and undeveloped possibilities of electric waves, nine years elapsed without a single practical or commercially successful result, and that Marconi was the first to describe and the first to achieve the transmission of definite intelligible signals by means of Hertzian waves.[ii]

Süsskind in his well-known series of articles entitled "The Early History of Electronics," which appeared in multiple issues of the *IEEE Spectrum* published between 1968 and 1970, echoed Townsend's opinion.[iii]

A few years later, Hugh Aitken in his award-winning book published in 1976, *Syntony and Spark – The Origins of Radio*,

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made a strong case that Lodge sent telegraphic messages during the course of a lecture he gave at a meeting of the British Association at Oxford on August 14, 1894. If true, this would have predated Marconi's earliest telegraphic experiments by almost a year.[iv]

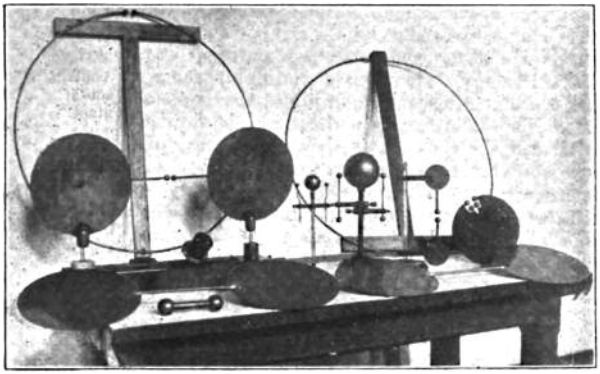

Fig. 1. Oliver Lodge used this equipment at Oxford to illustrate the quasi-optical properties of Hertzian waves and the effects of syntony in tuned circuits.

Aitken's book won the Dexter Prize awarded by the Society for the History of Technology as the best book published on the history of technology that year, thereby attracting wide attention among historians. Aitken presented evidence that Lodge had demonstrated signaling by Morse code at Oxford in 1894, quoting explicit claims that Lodge had done so by both Lodge and his close friend and associate, Silvanus Thompson.

Aitken posed the following questions, answered them in the affirmative with supporting evidence, and concluded that Lodge must be recognized as the inventor of radio telegraphy:

Did Lodge in 1894 suggest in public that his equipment could be used for signaling? Did his lecture refer to the application of Hertzian waves to telegraphy? Did he demonstrate transmission and reception of Morse code? The answer would seem to be affirmative in each case. In this sense Lodge must be recognized as the inventor of radio telegraphy.[v]

Respected historians and authors began to give priority to Lodge over Marconi, often repeating arguments appearing in Aitken's book. After many years, Aitken's book attracted the attention of Sungook Hong, Associate Professor of History at the University of Toronto. In the first few chapters of his book: *Wireless: From Marconi's Black-Box to the Audion,* published in 2001, he effectively refuted most of Aitken's arguments for Lodge's priority.[vi]

While Hong was convincing with his rebuttals, he never cited any proof that Lodge *did not* demonstrate telegraphy at Oxford. Absence of documentary proof may not be a concern for some, but others will be quick to point out that absence of proof is not the same as proof of absence, and that Lodge should be believed because he was a highly respected and honorable man.

Hong did not address the implication of his conclusions on Lodge's many claims of having demonstrated telegraphy at Oxford, namely that either his memory must have failed him or, worse yet, that he altered the truth in order to claim undeserved recognition. Hong avoided a direct attack on Lodge's character by claiming a nameless group of *"British Maxwellians*" were responsible for "*the re-characterizing of Lodge's 1894 Oxford demonstration as the first demonstration of wireless telegraphy*" because they *"thought that they should not hand over an ether monopoly to Marconi, who they thought had violated the rules of the game*."[vii]

In fact, it was primarily Lodge and Silvanus Thompson who re-characterized Lodge's demonstration as wireless telegraphy—not a nameless group of Maxwellians. Indeed, both the Maxwellians and the press took Marconi to task for copying or duplicating Lodge's equipment and claiming it as his own, but not for claiming priority in telegraphy.

For example, *The Electrician* was perhaps

the first to criticize Marconi for the claims in his patent. An article in its Nov. 12, 1897 issue made with the following accusation:

Both at Oxford and at the Royal Institution, Dr. Lodge described and exhibited publically in operation a combination of sending and receiving apparatus constituting a system of telegraphy substantially the same as that now claimed in the patent we have referred to.[viii]

The article was accompanied by two photographs of much, but not all, of Lodge's apparatus that was used or displayed at the Oxford demonstration (see Figs. 1 and 2). However, as Hong pointed out, the article did not claim Lodge had demonstrated telegraphy; it claimed only that Lodge's apparatus was substantially the same as that which Marconi described in his patent for wireless telegraphy.

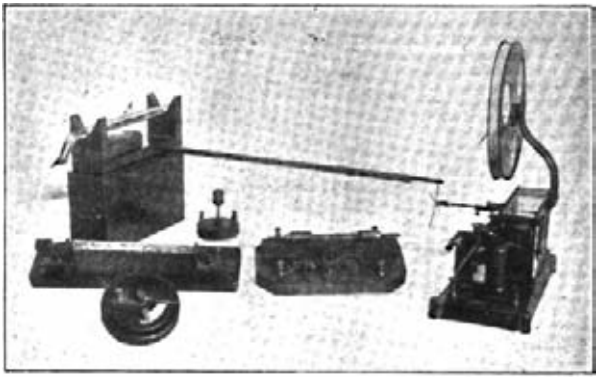

Fig. 2. Lodge displayed several coherers at Oxford including a point-contact spiral spring coherer (lower left), a Branly-type filing coherer (above the point-contact coherer), a filing coherer mounted on a board with a continuous buzzer restoring the coherer back to a sensitive state (center); and a filing coherer (upper left) tapped periodically by a rotating spoke attached to the clockwork mechanism of a siphon recorder (right).

The first claim that Lodge had transmitted telegraphic signals at Oxford in 1894 was made in passing by Silvanus Thompson in a paper he read at the Society of Arts on March 30, 1898.[ix] While this claim attracted very little attention, his next claim, made in a series of exchanges with Marconi in five issues of the *The Saturday Review* in 1902 attracted wide attention.

Thompson began the exchange with a vitriolic attack on Marconi in the April 3, 1902 issue, where he stated:

It seems like the irony of fate that Professor Lodge, the well-known Principal of the University of Birmingham, after expounding the principles of wireless telegraphy in London and at Oxford in 1894, should find himself pushed aside, first by the Italian, who by dint of advertisement gains the public ear...[x]

Thompson made the fatal mistake of claiming that Lodge expounded wireless telegraphy not only at Oxford, but also in London (at the Royal Institution). Lodge stated more than once that he did not mention or demonstrate telegraphy at his demonstration at the Royal Institution in London, thereby belying Thompson's claim. Indeed, Lodge's 1894 book, *The Work of Hertz and Some of His Successors,* which documented his London demonstration in detail, made no mention whatsoever of telegraphy. Thompson impeached himself in this exchange of letters more than once, and in such a biased and acrimonious manner that his pronouncements of Lodge's priority are not reliable.

Ironically, it was Thompson who framed the issue of priority by a retort appearing in *The Times* immediately following the exchange of letters in *The Saturday Review*. In response to a letter from by a Marconi supporter to *The Times* pointing out that Marconi had transmitted signals much further than Lodge, Thompson quipped: "*But that is not the point. The point is, Which of the two was the first to send a wireless telegram*?"[xi]

Lodge's Claims for Telegraphy at Oxford

By all published accounts, Lodge did not

make a claim for demonstrating telegraphy at Oxford until 1923, almost 30 years after the lecture. Lodge began with a relative modest claim in the Sept. 5, 1923 issue of *Wireless Weekly*, a claim which soon evolved into a more specific claim in his book, *Talks About Radio,* published in 1925:[xii]

It was now possible to use them [coherers] *for roughly and imperfectly transmitting signals in the Morse code either by the direct use of a Thompson marine speaking galvanometer or a siphon recorder…In August 1894, I exhibited this method of signalling at the British Association in Oxford.*

Lodge's claim matured into a final form in 1926, which he repeated several times in subsequent writings:

The possibility of actual signalling by this method was insisted on at Oxford… When the Morse key at the sending end was held down, the rapid trembler of the coil maintained the wave production, and the deflected spot of light at the receiving end remained in its deflected positions as long as the key was down; but when the key was only momentarily depressed, a short series of waves was emitted, and the spot of light then suffered a momentary deflection. These long and short signals obviously corresponded to the dashes and dots of the Morse code; and thus it was easy to demonstrate the signalling of some letters of the alphabet, so that they could be read by any telegraphist in the audience—some of whom may remember that they did so.[xiii]

These claims directly contradict a document published in 1907[xiv] where Lodge provides details of the telegraphic nature of his demonstration in 1894. The document entitled *Report of the Select Committee on Radiographic Convention* was prepared for the British House of Commons to assist them in determining whether or not it was in the national and public interest to ratify the Radiotelegraphic Convention, signed by British representatives attending the Convention in Berlin on Nov. 3, 1906. Committee members invited representatives from several British wireless companies including the Marconi's Wireless Telegraph Company and the Lodge-Muirhead Company to testify before the Committee, and the resulting testimony was recorded and published in July of 1907. Oliver Lodge was one of the two called to testify on behalf of Lodge-Muirhead on April 26, 1907. As far as I am aware, Lodge's testimony reproduced here (Fig. 3) has never been chronicled before, certainly not by Aitken, Hong or any other author dealing

Figure 3.

Oliver Lodge Testimony

Q. Would you mind telling me what was the first date and place at which you transmitted intelligible messages by means of the Hertzian waves?
A. You mean by intelligible messages on the Morse Code?
Q. Practically—yes.
A. Which conveyed intelligence?
Q. Yes, more than a mere signal which could be construed to be "Yes" or "No."
A. In my early experiments, and in the demonstration of 1894, I did not attempt to transmit words by Morse code; I used a Morse key and a mirror-signalling instrument, so that if I had been an expert telegraphist it would have been quite easy to send words, but all I did was to send short and long signals.
Q. That is to say, you claimed that you showed wireless telegraphy potentially but not actually.
A. That is so—not actually—no.
Q. But I gather from you that the idea of using Hertzian waves for practical telegraphic work did not occur to you until after you had heard of Marconi's achievement?
A. It occurred to Dr. Muirhead, who spoke to me about it, and who has his mind on telegraphy; but it did not especially interest me—not so specially.
Q. In fact it occurred to him, I understand you to say, after Marconi's?
A. No, after the 1894 demonstration.
Q. Before 1896?
A. Yes, in 1894 he was present at my lecture.
Q. But previous to 1896 you did not give the invention any personal application?
A. No.

with this controversy.

For clarity, the letter "Q" has been inserted before each question asked by the examiner for the Committee, and the letter "A" has been inserted to indicate Lodge's response. The examiner begins by asking Lodge where and when he first sent intelligible signals by means of Hertzian waves, and Lodge, after asking for a clarification, responds that he did not attempt to transmit by Morse code in his early experiments, and that all he did in his 1894 demonstration was to send short and long signals.

By stating that he sent long and short signals, Lodge is clearly referring to the Oxford demonstration—not the earlier demonstration at the Royal Institution in London. The examiner then asks if Lodge showed wireless telegraphy "potentially, but not actually," and Lodge responds "not actually—no." The examiner then asks if the idea of using Hertzian waves came to him after he had heard of Marconi, and Lodge responds that it came not to him, but rather to Dr. Muirhead.

After the examiner asks for clarification, Lodge then says that it came to Muirhead after the 1894 demonstration. So, Lodge is saying that it was not his idea, and further, that the idea of telegraphy by Hertzian waves came to Muirhead *after* the 1894 demonstration—clearly the demonstration to which he referred earlier—that is, the Oxford demonstration. If the idea of telegraphy by Hertzian waves was conveyed to Lodge after his Oxford lecture, then he clearly did not refer to or demonstrate telegraphy at Oxford.

This conclusion is supported by another unchronicled document that clearly indicates Lodge did not make a telegraphic presentation at Oxford. The document is an abstract of Lodge's Oxford demonstration entitled "Hertzian Waves" that appears in the August 24, 1894 issue of the Weekly Supplement to *The Electrical Engineer*.[xv]

It is clear that Lodge himself prepared the abstract not only because of the byline, "By Prof. Oliver Lodge," but also because of the opening line: "The author described…" Since Lodge did not write a paper covering his lecture, the only document he could have authored was the abstract itself. Further, bylines were not used by the *Electrical Engineer* when the summaries were prepared by editors of the magazine.

For example, see the summary of Lodge's lecture at the Royal Institution of London in June in the same journal, which was clearly prepared by the editors and has no byline.[xvi] It begins with "*Prof. Oliver Lodge discoursed…*" Heretofore, historians and biographers have assumed that Lodge did not document any account of his Oxford lecture,[xvii] but it now appears that he did.

There are three points to be made about the contents of this abstract. First, there is absolutely no mention of telegraphing. Second, there is no mention of long-distance transmission of signals from distant rooms. Instead, it states:

The coherer could detect the surgings in a sphere 5 ft. away when charged by an electrophorus, or the oscillations of an electric lighter; in Liverpool a sphere nearly 70 yards distant had affected the instrument.

This statement strongly implies that no long-distance signaling occurred at Oxford—otherwise the abstract would have referred to long-distance signaling at the Oxford lecture rather than earlier at Liverpool. Thompson had claimed that Lodge's demonstration of telegraphy at Oxford was accomplished with signals coming from the Clarendon Laboratory at a distance of 60 or so yards, and so it appears that Thompson was once again dissembling about Lodge's telegraphy at Oxford. Third, the abstract indicates that the shorter and longer pulses—often referred to later by Lodge as evidence of the "dots" and "dashes" of Morse code—were made in the context of demonstrating persistence of vision, not in the context of telegraphy:

Between the stimulus of light and that of darkness there would be persistence of vision. Dr. Lodge showed an experiment to illustrate this, the coherer being restored by periodic tapping applied by a clockwork.

For a continuous radiation [i.e., long pulses] *the coherer showed continuous indications, which died away when the radiation ceased.*

Conclusions

Lodge testified unequivocally that he did not send words by Morse code in the 1894 demonstration. Specifically, he stated: *"... all I did was to send short and long signals*." Thus, he did not even transmit letters of the alphabet by Morse code, as he later claimed. The abstract of his Oxford lecture supports the contention that he transmitted short and long signals to demonstrate persistence of vision, not telegraphy.

Perhaps he later reinterpreted his short pulse of radiation as being an "S" and his long pulse as being a "T," but that is not telegraphy; otherwise, anyone who experimented with transmission and reception of Hertzian waves by sending pulses of different lengths for any reason could make the same claim.

Lodge also testified that the idea of Hertzian telegraphy was communicated to him by Muirhead "*after the 1894 demonstration*," which, by his previous reference to transmitting short and long pulses in the demonstration of 1894, was a clear reference to the Oxford demonstration. Lodge then testified that Muirhead's suggestion of Hertzian telegraphy "*did not especially interest me*." Clearly, it did not because Lodge did nothing more with Hertzian waves after Oxford until Marconi's method of telegraphy with Hertzian waves became known in England two years later.

It should be noted that Sungook Hong arrived at exactly the same conclusion, albeit using a different set of source documents. In that sense, the two efforts are complimentary rather than duplicative. The main difference between the two is that Hong concludes there is no real evidence to support Lodge's claim of telegraphy at Oxford, while the conclusion drawn here is that Lodge's testimony and abstract provide irrefutable evidence that he did not demonstrate telegraphy at Oxford.

It is instructive to contrast Lodge's previously unchronicled testimony about his Oxford demonstration presented here with the conclusion reached by some of the more prominent historians in the last 40 years. Clearly, these respected historians came to conclusions about his Oxford lecture that are completely at odds with Lodge's testimony:

- Peter Rolands (1990): *On 14 August, at the British Association meeting in Oxford, Lodge gave the world's first demonstration of radio signalling in Morse code using electromagnetic waves*.[xviii]
- George Basalla (1988): *In 1894 Lodge...sent signals in Morse code across a distance of 180 feet and discussed the possibility of radio telegraphy*.[xvix]
- Roland F. Pocock (1988): *Lodge had shown how Morse signals could be transmitted and received by Hertzian radiation...*[xx]
- Hugh G. J. Aitken (1976): *Did Lodge in 1894 suggest that his equipment could be used for signaling...Did he demonstrate transmission and reception of Morse code? The answer would seem to be affirmative in each case*.[xxi]
- W. P. Jolly (1974): *...a few letters were transmitted for the benefit of the audience. This was the first public demonstration of radio telegraphy...*[xxii]

There are still a few loose ends yet to be tied up in Part II of this article. For example, could Lodge have actually demonstrated telegraphy using Morse code with the apparatus he used at Oxford? Was Marconi's system essentially the same or substantively different from the apparatus Lodge used at Oxford? Why did Lodge wait almost 30 years after his Oxford lecture in 1894 before he made his first claim that he demonstrated telegraphy there? Did Lodge merely stretch the truth or did he make false statements?

REFERENCES

i For example, Russell W. Burns awarded priority to Lodge in his book *Communications: An International History of the Formative Years* (Institution

(continued on page 60)

34-49 Features.TV_Radio Rep-Obits 1/13/14 11:48 AM Page 34

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PART 2 — CONCLUSION

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Many historians have accorded priority to Lodge over Marconi for demonstrating Hertzian telegraphy based on claims made by Lodge later in life that he first transmitted letters and messages by Morse code in his 1894 lecture at Oxford—even though there are no contemporaneous documents that support Lodge's claims. It was only after Marconi documented his apparatus for Hertzian telegraphy in his patent published on June 2, 1897 that Lodge began to allude to earlier signaling:

"*I myself showed what was essentially the same plan of signalling in 1894*," referring to Marconi's apparatus.[i] He further stated: "*My apparatus was substantially the same as that now used by Signor Marconi…and by employing greater power he has obtained signals over much greater distances*."

Based on documents presented in Part I of this article (in the Autumn 2013 issue), we now know from Lodge's own admission in testimony before a committee appointed by the British parliament in 1906 that he did not send telegraphic messages or letters using Morse code in 1894 or at any other time prior to Marconi's arrival in England in 1896. Lodge specifically stated:

"*I did not attempt to transmit words by Morse code; I used a Morse key and a mirror-signalling instrument, so that if I had been an expert telegraphist it would have been quite easy to send words, but all I did was to send long and short signals*."[ii] Lodge then equivocated by agreeing with the examiner that at Oxford he "*showed wireless telegraphy potentially but not actually*."

Lodge's equivocal claim raises several interesting and related questions. Is the transmission and reception of long and short signals sufficient to demonstrate "wireless telegraphy potentially?" If Lodge had attempted to demonstrate telegraphy with his 1894 apparatus, what word rate and distance could he have achieved? Was Lodge's apparatus substantially the same as that of Marconi, as Lodge asserted? These questions can be answered by comparing Lodge's 1894 apparatus and telegraphic capabilities (i.e., word rate, error rate and range) with those of Marconi's 1897 apparatus.

Marconi's 1897 Apparatus

For purposes of comparing Marconi's 1897 apparatus and performance with those of Lodge's 1894 apparatus, Marconi's demonstration tests between Bournemouth and Needles in England beginning in November 1897 will be used as a baseline. The data reported are deemed to be reliable because there were independent observers present including Prof. Adolf Slaby, representatives of the British General Post Office, and an editor for *The Electrical Review* where the data was published.[iii]

Marconi's apparatus was essentially the same as that documented in his fundamental patent issued in June of 1897.[iv] The key components of the transmitter were a Ruhmkorff coil powered by six accumulator-cells and a Righi oscillator with one end grounded and the other connected to a capacitively loaded monopole antenna, all of which are shown in Fig. 1 except for the antenna. The Ruhmkorff coil had a pulse repetition rate on the order of 100 pulses per second (pps), with each pulse having a duration of ~ 1-3 μsec.

The receiver consisted of an improved

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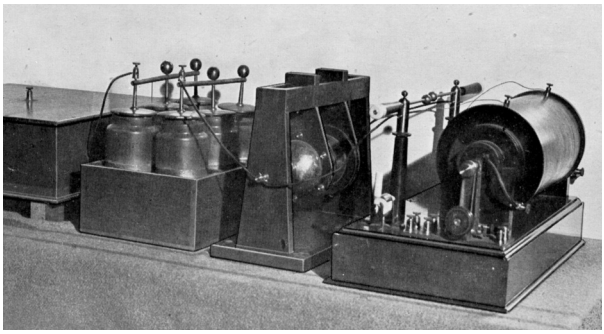

Fig. 1. In 1897, Marconi's transmitter generated spark signals with a Righi oscillator, which was connected to an antenna (not shown) and excited by a 10" Ruhmkorff coil that was powered by six accumulator cells. (J. IEE, Vol. 91, Mar. 1944)

silver and nickel filings coherer with one end grounded and the other end connected to an antenna similar to the one used for the transmitter. The coherer was also connected to a series circuit with a battery, two RFI chokes and a low-voltage relay, which was activated to connect a second battery to a tapper-back hammer and ordinary Morse recorder whenever signals representing the dots and dashes of Morse code were applied to the coherer.

Key parameters reported for the Bournemouth test were monopole antennas with heights of 115 feet (resonant at ~ 2 MHz), an antenna separation distance of 14.5 miles, and a 10" Ruhmkorff coil powered by "a few cells underneath the table." An average word speed of 12 words per minute (wpm) was reported for tests designed to measure the error rate rather than word speed. Coded messages were sent with the request they be repeated back so that errors could not be detected based on the meaning and surreptitiously corrected. It was reported that "the code message came back exactly as it was sent."

Lodge's 1894 Apparatus

Lodge did not describe the configuration he used to send long and short signals during his Oxford lecture in 1894, but he did file a U.S. patent for wireless telegraphy in 1897 describing several configurations of his 1894 apparatus that he claimed were suitable for telegraphy.[v] The spherical emitter shown in his patent and also in his 1894 book, *Work of Hertz*,[vi] was placed inside a partial metal enclosure to diminish waves radiated in undesired directions (see Fig. 2).

Lodge, like Marconi, used a Ruhmkorff coil (not shown) to generate high-voltage pulses that were applied to two small spheres located on either side of the larger 6" emitting sphere by means of the two wires entering the enclosure to the left. The two small spheres produced discharges on opposite sides of the emitting sphere that set it into oscillation, thereby producing electromagnetic radiation with a nominal wavelength of 9" (23 cm) that exited through an opening in the enclosure to the right.[vii] There is strong evidence that this is the source he used to

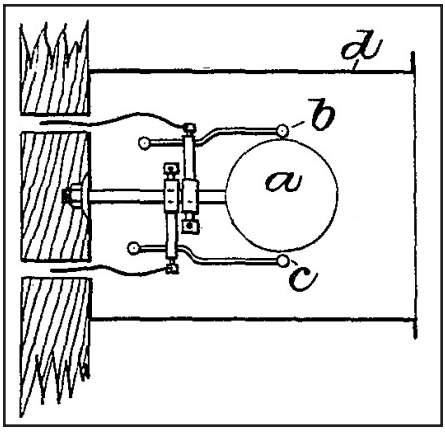

Fig. 2. Lodge's 1894 emitter at Oxford consisted a copper enclosure (d) containing a 6" spherical emitter (a) excited by two smaller spheres (b & c) that sparked to the larger sphere, which radiated waves out of the opening on the right; wires leading out of the back of the enclosure were attached to a Ruhmkorff coil. (U. S. Patent 764,846, 5/1/1901)

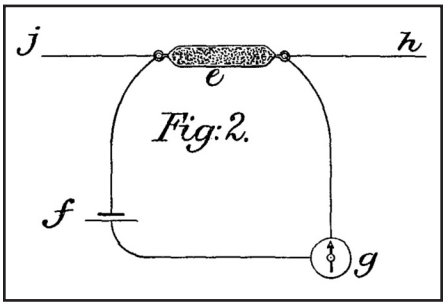

Fig. 3. Lodge's 1894 receiver consisted of a coherer (e) in series with a battery (f) and a Kelvin marine galvanometer (g); the two stubs (j & h) represent antenna attachment points, which were not used in the 1894 experiments at Oxford. (U. S. Patent 764,846, 5/1/1901)

generate long and short pulses during his vision experiments at Oxford.

The receiver shown in Lodge's patent consisted of a Branly-type tube coherer with iron and brass filings, which was connected in series with a battery and a galvanometer for reading the signals (see Fig. 3). Later in life, Lodge described the equipment he used in signaling at Oxford as follows: "*The tube of filings was provided with a tapping back arrangement, which restored them to sensitiveness directly* [after] *the wave subsided*."[viii]

Actually, Lodge's tapping back arrangement was driven by a clockwork spring and therefore could not have restored the coherer directly after each wave subsided, as he claimed (see Fig. 1 in Part 1). It is interesting to note that Lodge said he picked the tapping period of 0.1 second "*so as to give the right amount of persistent of impression*" for the eye—not for signaling or telegraphy.[ix] Indeed, the electrical journals reported that Lodge's clockwork-driven tapping apparatus was used specifically in his vision experiment at Oxford with a tapping period of 0.1 second—prima facie evidence that Lodge received the long and short signals in the course of his vision experiments, not during a telegraphy demonstration.[x]

Lodge also stated that he used "*a Kelvin marine galvanometer, as first used for Atlantic telegraphy*" for the readout device.[xi] Lodge further claimed that the galvanometer "*responded to signals sharply, in a dead-beat manner* [critically damped], *without confusing oscillations*," noting that "*When the Morse key at the sending end was held down…the deflected spot of light at the receiving end remained in its deflected position so long as the key was down; but, when the key was only momentarily depressed, a short series of waves was emitted, and the spot of light then suffered a momentary deflection.*"

Word Rate Capability of Lodge's Apparatus

Lodge never published any telegraphic performance data using his Oxford apparatus—not even after Marconi came to England, which gives pause for thought because it would have been a good opportunity for him to demonstrate that he had used "*essentially the same plan of signalling in 1894."* Neither contemporaneous engineers nor later historians questioned the capability of Lodge's 1894 apparatus to receive messages in Morse code—at least over short distances. Apparently, there was a tacit assumption that since Lodge used a Kelvin galvanometer, which had a demonstrated capability to read words up to at least 20 wpm on the Atlantic cable, he must have been able to read words at comparable rates with Hertzian signals.

For example, when J. A. Fleming pointed out that a key distinction between Lodge's and Marconi's apparatus was Marconi's use of a Morse recorder in place of the Lodge's galvanometer, Sir Charles Bright, a distinguished engineer responsible for overseeing the installation of the Atlantic cable in 1858, responded in the press as follows:

"*…when he* (Fleming) *talks of Sir Oliver Lodge 'affecting a coherer and so moving the needle of a galvanometer,' he appears to forget that much signalling is done by a mirror galvanometer, and that neither Mr. Marconi nor anybody else could claim a monopoly on the grounds of substituting a galvanometer by a Morse recording instrument or a telephone*."[xii]

What has not been noted by Lodge, Bright or even later historians is that that the signals read by the Kelvin marine galvanometers used on the Atlantic cable were substantively different from those generated by the coherer circuit in Hertzian telegraphy. The Kelvin marine galvanometer was designed to read a modified form of Morse code in which dots and dashes were represented by positive and negative signals of *equal* duration rather than the long and short unipolar signals of conventional Morse code generated by the coherer in Hertzian telegraphy.

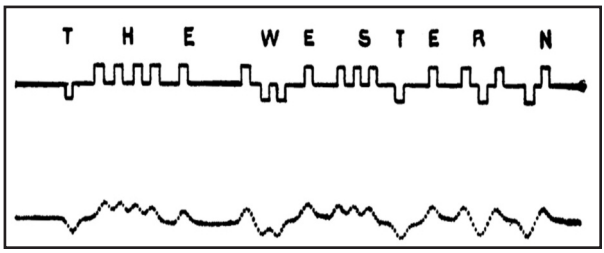

*Fig. 4. Morse code signals transmitted on the Atlantic cable consisted of equally spaced dot and dashes with positive and negative polarities respectively; they were initially read visually with a Kelvin galvanometer, and later inked onto a siphon recorder tape such as the one shown below. (*Submarine Telegraphy*, Western Union)*

An example of a signal transmitted and received on the Atlantic cable using a marine galvanometer is shown in Fig. 4.[xii] Positive and negative signals of equal duration used on the Atlantic cable produced distinguishable needle swings equidistant above and below a zero baseline, which were easily read by one person and recorded by another. As far as I am aware, no one has documented the ability to read Morse code messages with a Kevin marine galvanometer at practical word rates coded with signals of long and short duration.

The basic problem in using any galvanometer to read a sequence of long and short Morse code signals at practical word rates is that after a deflection of the needle caused by short electrical pulses representing either a dot or dash, there is generally insufficient time for the needle to return to zero or even back to the original position in the space that follows before the next dot or dash arrives—particularly for the shortest spaces in Morse code having a duration equal to one dot (e.g., 0.1 sec at 10 wpm). As a result, subsequent deflections begin and end at different points on the scale, and have a variable length that depends not only on the word speed but also on the past sequence of signals. Under certain circumstances the deflections can be of the same length for both dots and dashes—making them indistinguishable.

I observed this to be the case during several experiments in which a series of dots, dashes and intervening spaces at word rates between 1 and 20 wpm were applied to a D'Arsonval galvanometer. Lacking access to a Kelvin galvanometer, I used a D'Arsonval galvanometer with a one-way swing time of one second as a surrogate test bed for the Kelvin galvanometer. The literature reports swing times from 1 to 10 seconds for Kelvin marine galvanometers, depending on the design and sensitivity.[xiv] Larger swing times result in greater difficulty in reading signals.

I repeated these tests with actual Morse code signals using an Omnigraph device to generate actual messages at word rates from 1 to 20 wpm, and found it virtually impossible to reliably distinguish many dots from dashes at word rates above 3-4 wpm. I then performed experiments using positive and negative signals of equal length representing the dots and dashes of Morse code used on the Atlantic cable. Two telegraph keys and two batteries wired with opposite polarities were used for this experiment. The needle swings for dots and dashes were of equal length, and because they were propelled by positive and negative electrical pulses respectively, they were easily distinguished by their respective positions either to the left or right of the zero point, even up to a rate equivalent to

20 wpm.

While the results of the experiments with a D'Arsonval galvanometer cannot necessarily be used to quantify the response of Lodge's Kelvin galvanometer, they do demonstrate that the ability to receive a long and a short pulse and distinguish between them is not the same as the ability to receive and read telegraphic messages at practical word rates.

There are additional problems with Lodge's receiving apparatus, one of which is his clockwork tapping back arrangement that introduces significant errors in the reading of Morse code above 5-10 wpm. For example, at 10 wpm, each dot of Morse code has a duration of 0.1 sec, which in Lodge's apparatus is created by approximately 10 consecutive pulses of ~ 1-3 μsec duration, each generated by the Ruhmkorff coil operating at 100 pps as shown in Fig. 5.

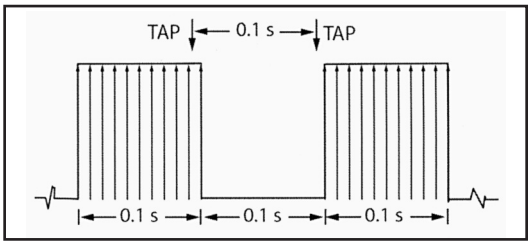

Fig. 5. The coherer in Lodge's receiver, which is activated by ~ 1-3 μsec pulses spaced at 0.01 sec., remains active until tapped back by a clock-work hammer with a period of 0.1 sec.; consequently a single pulse arriving after the last tap and just before the space at the end of a dot with duration of 0.1 sec. (corresponding to 10 wpm) can cause conduction during the entire space—thus turning a dot-space-dot into a dash.

Lodge's tapper with a tap period of 0.1 sec. will strike randomly at some point during the ten pulses that form each dot, also of duration 0.1 sec, and therefore will have a 10% probability of striking just before the last pulse in the dot—t*he case shown in the figure. The last pulse in the dot* activates the coherer and places it in a conducting state until the next tap, which does not occur until the end of the rest. Thus, the coherer conducts for the entire rest, and so the two dots separated by one space (e.g., two e's) will be read as a dash (i.e., one t).

Just under half the letters in Morse code are represented by two or more dots separated by a single space, so messages at 10 wpm or more will be totally unintelligible. Error rates will diminish as the word rate decreases below 10 wpm, but will still be significant, even at 5 wpm.

Distance Capabilities of Lodge's 1894 Apparatus

Lodge reported that he had received signals at 40-60 yards with his point-contact coherer which, according to him, had a greater range of sensitivity than the filings coherer he used to generate long and short pulses. Based on these measurements, he estimated for his apparatus "*something more like half* [a] *mile as nearer the limit of sensitiveness*."[xv] In sharp contrast, Marconi had demonstrated the capability to send actual Morse code signals a distance of 14.5 miles in 1897—at the very time Lodge claimed his apparatus was essentially the same as Marconi's.

Lodge asserted the main reason for the discrepancy in distance was due to the source power: "*by employing greater power, he* [Marconi] *has obtained signals over much greater distances*."[xvi] However, there was actually little difference in source or spark energy used in Marconi's 1897 demonstration. The press reported Marconi used a 10" Ruhmkorff coil with "several cells below the table," while Lodge stated he used a similar Ruhmkorff coil in his 1894 demonstration experiments. Nevertheless, critics of Marconi apparently believed Lodge because they, too, would not acknowledge there was any significant difference in the apparatus.

The real reason for the huge discrepancy in ranges was the sizes of their respective transmitter and receiver antennas. Lodge chose to radiate very short wavelengths so he could more readily demonstrate optical

properties of electromagnetic waves in lecture rooms, and never gave any thought to extending the range of his apparatus for telegraphic purposes. Consequently, he chose a six-inch spherical radiator that emitted wavelengths of 9 inches (.22 m or 1.3 GHz),[xvii] which was suitable for his objectives, but entirely unsuitable for telegraphy.

On the other hand, Marconi was intent on demonstrating wireless telegraphy at practical distances, and he determined experimentally that longer distances could be obtained with larger antennas. We now know that the energy spectrum of the spark discharge was broadband, extending from a few kilohertz to several gigahertz, with the greatest energy content at frequencies well below the resonant frequency of Lodge's emitter. We also know that the larger antennas Marconi used radiated vastly more energy than the smaller antenna Lodge used.

As the antenna became larger, the resonant frequency decreased and Marconi's antenna was able to radiate more of the spark spectrum, which was rich in low-frequency content. Not only that, Lodge's spherical emitter, like a loop, was an inefficient radiator as compared to a dipole of equivalent size. Last but not least, it is well known that Marconi discovered that by grounding his antenna circuits, he increased both the radiated and received power by as much as a factor of four, for a total increase of 16 in system sensitivity.

Summary and Conclusions

It is clear that Marconi's apparatus was substantively different from that of Lodge in two important areas. First, Marconi used a tapper-back hammer and a Morse inker that was activated by a relay only when signals were present, thus avoiding the problems noted with Lodge's apparatus. Marconi demonstrated word rates of 12 wpm with minimal errors in 1897, and Preece observed that Marconi's small vibrating hammer head "*makes such a sound that reading Morse code characters was easy*."[xviii]

Lodge's demonstrations were limited to short and long pulses lasting perhaps a few seconds. Had Lodge actually tried to transmit Morse code, his word rates would have been limited to a few words per minute without significant error rates due to his galvanometer and clockwork-tapper. Bright's claim that Fleming "*appears to forget that much signaling is done by a mirror galvanometer*" ignored the problems in reading Morse code unique to Hertzian telegraphy.

For example, the signaling by the marine mirror galvanometer on Atlantic cables had been demonstrated only for a substantively different form of Morse code in which positive and negative signals of equal duration were used to represent dots and dashes rather than the unipolar pulses of unequal lengths produced in Hertzian telegraphy. It is clear that Marconi's receiver arrangement with a relay was a significant invention that allowed the signals to be read and recorded at practical speeds needed for telegraphy.

Second, Marconi developed large monopole antennas with grounded transmitter and receiver circuits specifically to achieve long ranges that he knew were needed to demonstrate practical telegraphy. Lodge, on the other hand, used small and inefficient spherical emitters and a receiver with only the interconnecting wires to act as a loop antenna for his demonstrations, giving no thought for achieving longer ranges needed for telegraphy.

When Lodge became interested in telegraphy after Marconi's patent was issued in 1897, it was Lodge who essentially copied Marconi's designs by replacing his galvanometer with a siphon recorder (similar in function to Marconi's Morse inker), replacing his small spherical emitter with a large dipole antenna, and adding a large antenna to the receiver circuit needed to receive the longer wavelengths emitted by his new long-wavelength transmitter.

It was often said by critics of Marconi that his 1896-7 apparatus was essentially the same as Lodge's 1894 apparatus, differing only in detail. In the sense that both used spark discharges to generate Hertzian waves and coherers with tapper-back

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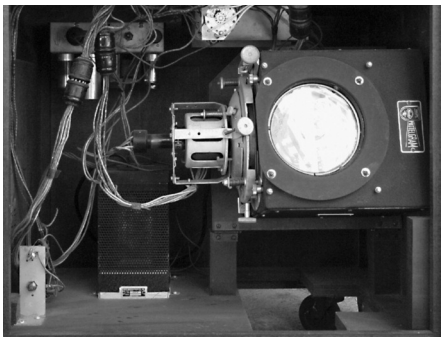

The cabinet contains a Norelco Protelgram projection unit plus a three-tube "conversion unit" and associated high- and low-voltage power supplies.

sion unit as well as for 3NP4 focus voltage. The original TV does not provide any power for the *Duo-Vue*.

The *Electrical Engineering* article (3) suggests that the resultant 3 by 4 foot picture could actually be better than that of the original set. One would have expected the *Duo-Vue* to be a big hit. But by August of 1951, Allied Radio was offering the unit for only $87.50, "less than factory cost (1)." One can only assume that a big picture was not in big demand. Yet, *Midwest Television* was advertising a "MAMMOTH" 20-inch set in the same August publication. In addition, USS Stainless Steel was promoting the availability of 21-, 24- and 30-inch metal picture tubes. History tells us that most of the pubic was quite happy with only a 27-inch set until very recently. Now, with the advent of large flat-screen models, nothing less than a 50-inch set will do!

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1. Radio and Television News. August 1951.
2. Radio & Television News, May 1950.
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Note: Some documentation provided by Early Television Foundation.

RESEARCHING, *continued from page 39*

hammers as detectors, the statement is true. However, in the sense that Marconi's apparatus was demonstrably suitable for telegraphy and Lodge's was not, they were vastly different in the details that were important. Consequently, Lodge's claim in 1897 that Marconi's apparatus was substantially the same as his is specious.

It is also clear that merely sending long and short signals of unspecified length is not sufficient to demonstrate telegraphy—even potentially—and further, Lodge had no way to extrapolate the results of his limited experimental data to determine if his apparatus could be made practical for telegraphy in both word speed and range. History would reveal that when Lodge became interested in developing a practical Hertzian telegraphy system in 1897, the design of his system and the components he used were totally different from his 1894 apparatus. Consequently, his claim that he "*showed wireless telegraphy potentially"* in 1894 is also specious.

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[vi] O. Lodge, *Work of Hertz and Some of His Successors*, 1894, p. 31.
[vii] O. Lodge, "Hertzian Waves," *Elect. Engr.*, Vol. 14, Aug. 24, 1894, p. 212.
[viii] O. Lodge, *Past Years*, (Charles'

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