François van Rysselberghe: Pioneer of Long-Distance Telephony

D. GORDON TUCKER

François van Rysselberghe (1846–93) has largely escaped the notice of historians of technology and is, to my knowledge, mentioned in only one modern book on the history of electrical communications.[1] Yet his contribution to the early establishment of long-distance telephony in the first decade of telephone development was large, although almost entirely outside the United States and Britain. His system of superposing telephone circuits on existing telegraph lines enabled long-distance telephone systems to be established where they might otherwise have been uneconomic. Even in the United States he demonstrated in the winter of 1885–86 how good telephone conversation could be carried over 1,000 miles of busy telegraph line. Let us first consider the background of telephone development.

By the time the telephone had become a commercial possibility in 1877–78, the telegraph network had grown to large dimensions, aggregating throughout the world over 1.5 million miles. It had been commercially viable for around four decades and was handling a vast traffic, linking most parts of the world. In many countries there were thousands of miles of pole routes where several, often many, wires ran parallel to one another at quite close spacings, and interference between wires had become a serious problem.

At first the telephone was not seen as a means of long-distance communication, and it was used for local communication only. But the growth of telephony was nevertheless rapid. By 1880 the United States had over 60,000 telephones and 100 exchanges, and by the end of 1885 there were nearly 333 thousand telephones and 782 exchanges. (The growth in Britain was startlingly less rapid—only 13,000 telephones by the end of 1885.)

Naturally, a demand soon began to arise for interurban and long-

DR. TUCKER has been a communications engineer, a sonar engineer, and, from 1955 to 1974, professor of electrical engineering at the University of Birmingham, England. He is currently Senior Fellow in the history of technology at Birmingham.

[1]Bell Laboratories, *A History of Engineering and Science in the Bell System* (1975), p. 240.

distance communication by telephone. By 1885 this was provided in the United States by a network of "toll" lines extending to a total route mileage of just over 31,000, about two-thirds of which was single-wire circuit forming the sole load on its pole route. Interference problems were thus largely nonexistent over much of the mileage, but satisfactory communication was nevertheless limited to around 100 miles. Traffic was sparse.[2] In Europe, interurban telephone routes were seen as rivals to the telegraph system which was, in each country, a government monopoly, and consequently they developed more slowly than in the United States. This was particularly true in Britain, where there had been government restrictions on interurban telephony until 1884.[3]

In the more densely populated areas of America and Europe, including Britain, interurban telephone lines had to be run adjacent to telegraph lines, and the interference produced by the sudden changes in current as the telegraph signals were keyed on and off—which we have already mentioned as causing trouble even in telegraphy—became intolerable on the telephone circuits. It was known that one cure for this "induction," as it was called, was to use double-wire loop circuits (then called "metallic" circuits to distinguish them from earth-return circuits) so that the induction would tend to cancel out. These were later used in the United States to develop a long-distance network after 1888. Most telephone organizations in the early 1880s, however, stuck to single-wire circuits on grounds of cost, and while communication up to 60 miles was said to be possible in the evenings, when the telegraph offices were relatively quiet, it was not possible—or at any rate, not satisfactory—during the day.

It was in response to this situation that van Rysselberghe put forward his proposals for the satisfactory working of telephone lines, not only in juxtaposition to telegraph lines but actually superposed upon them. Successful experiments led to widespread adoption of his system.

Against this background we will now consider van Rysselberghe in more detail. I have been unable to discover any biography of him, and a short note to which Professor J. B. Quintyn of Ghent (Belgium) was kind enough to draw my attention omits major features of his career.[4] Thus, we will commence with a short biography before proceeding to the major section of this study—the invention and development of

[2]Data from W. H. Preece, "Long-Distance Telephony," *Journal of the Society of Telegraph Engineers* 15 (1886): 274–303.

[3]*Electrician* 20 (1888): 437–38.

[4]J. S. van Berchem, *Stroofjes over enkele belgische uitvinders uit de XIXe eeuw* (Brussels, 1966).

van Rysselberghe's system of simultaneous telephony and telegraphy and its rapid application in Europe and elsewhere, including his remarkable experiments in the United States. We will report and discuss some objections to the system, and some criticisms and controversies, especially in relation to the highly successful international telephone system between Paris and Brussels, opened in 1887 with van Rysselberghe's equipment. The article concludes with a discussion of the novelty of van Rysselberghe's system and an attempt to sum up his achievement.

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François van Rysselberghe was born in Ghent on August 25, 1846. At the very early age of seventeen he was appointed a professor at the Ostend School of Navigation and shortly afterward professor of physics at the Industrial School. He was also a hydrographic engineer.[5] There can therefore be little doubt of his brilliance. His diligence must also have been outstanding, for he invented several important instruments and, having become attached to the Belgian Royal Observatory, became editor of the *Bulletin météorologique* in 1877. A telemeteorograph which he developed with the constructional assistance of Schubart of Ghent and which recorded, locally or at a distance, readings from a barometer and from wet- and dry-bulb thermometers, wind direction and velocity, and rainfall attracted wide attention.[6]

It was van Rysselberghe's system for carrying telephone traffic on existing telegraph lines without excessive mutual interference between telephone and telegraph signals, first made public in 1882, which brought him fame. He thought the whole system out very completely, embracing single-wire and loop-circuit working, the concept of phantom circuits (as they were called at a later date), the proper use of transformers, and other features. I believe, as I try to show later, that he was the first inventor of a satisfactory system of simultaneous telephony and telegraphy on the same wires. Although he later had rivals, his arrangements were probably the most correctly designed and most certainly the first to be put into practical operation. Long-distance telephone lines based on his system formed most of the world's interurban telephone network outside the United States in the 1880s, and his influence was to be seen in almost every continent.

During the winter of 1885–86 van Rysselberghe went to the United States to make a long series of experiments to determine the limiting distances over which telephony was possible on different kinds and

[5]"M. François van Rysselberghe," *Le Globe illustré* (Brussels) (June 13, 1886), p. 425.

[6]"Van Rysselberghe's and Schubart's Meteorograph," *Electrician* 9 (1882): 301–3.

gauges of wire. He was understandably excited when he achieved good speech over a 1,000-mile line between New York and Chicago. From this result he deduced that, given suitable wire, transcontinental telephony was feasible. His influence in the United States, however, seems to have been rather less than in other parts of the world. Indeed, seven years later the president of the American Telephone and Telegraph Company, obviously unaware of van Rysselberghe's work, claimed that his company's recent achievement (in 1892) of telephony over a 1,000-mile line was the first ever![7] In fact, there had been claims for speech over 1,000 miles even before van Rysselberghe's experiment,[8] but I can find no detailed evidence for these. Whether these claims were true or not, it seems certain that van Rysselberghe did score a first: his 1,000-mile speech transmission took place over a line which was simultaneously carrying busy telegraph traffic.

The real importance of van Rysselberghe's system of simultaneous telephony and telegraphy was that it enabled a long-distance telephone service to be provided on existing telegraph wires at a time the demand for such service was not really established, and it was not therefore thought economic to provide the separate and isolated telephone routes that would otherwise have been needed. It was thus, in many countries, only through van Rysselberghe's work that long-distance telephony became established as early as the mid-1880s. However, there were some difficulties associated with the use of his system. Very high telegraph speeds had to be avoided if interference with speech was to be kept at the very low level needed for the very long routes, and his calling signals were found to produce some interference. There was some dissatisfaction with his system in some countries as the expected standards of telephone communication began to rise from those associated with a novelty to those of a regular essential commercial service. It was only natural, therefore, that his system should be eventually displaced by separate telephone and telegraph lines as business increased and made such separation economic.

Van Rysselberghe formed a business association with Charles Mourlon of Brussels, who was a manufacturer of electrical equipment. Together they sold licenses and apparatus for the van Rysselberghe system all over the world. Evidently the company was well backed financially, for in August 1889 it approached the British and French governments regarding the first cross-Channel telephone cable then being planned.[9] Van Rysselberghe himself went over to London (and probably also to Paris) to propose that his company

[7]Quoted in F. L. Rhodes, *Beginnings of Telephony* (New York, 1929), pp. 201–2.

[8]*Electrician* 4 (1879): 38; ibid., 10 (1883): 458.

[9]D. G. Tucker, "The First Cross-Channel Telephone Cable: The London–Paris Telephone Links of 1891," *Transactions of the Newcomen Society* 47 (1977): 117–32.

should itself provide the cable, and simultaneous telegraph and telephone transmission upon it, at a cost of £20,000,[10] their return being merely the expected royalties on the telephone traffic. The proposal was turned down by the governments, however, as they wished to keep the whole project in their own hands.

Surprisingly, van Rysselberghe, backed by Mourlon and others, also attempted to enter the field of public electricity supply by putting forward proposals for electricity supply in Brussels in 1889. His scheme was a novel one and, no doubt because of his high standing, was taken very seriously in Brussels; so much so, indeed, that he was given a concession to supply a large area of the city—the quartier Notre Dame aux Nieges, the quartier Leopold, the avenue Louise, and a portion of the south of the town. His system was a curious hydroelectric one, based on high-pressure hydraulic mains and individual small waterwheel-generators at each consumer's premises and at each group of street lamps. A contemporary account stated that "M. van Rysselberghe thinks that the constant cleansing of the city sewers by the used water ought alone to ensure the adoption of his plan, apart from any consideration of its superior economy." Unfortunately, the system would be very costly, and when the whole Brussels electricity-supply proposal was reappraised in 1890 van Rysselberghe's scheme was tactfully dropped.[11]

Van Rysselberghe lived very little longer, dying on February 3, 1893 at Antwerp at the age of forty-six.[12] He had, however, achieved considerable distinction; he was awarded a gold medal at the International Electrical Exhibition in Paris in 1881 for his telemeteorograph; he was made a Chevalier of the Legion of Honour, also in 1881; and he was made a Chevalier of the Order of Leopold in 1884.

The van Rysselberghe System of Simultaneous Telephony and Telegraphy

Van Rysselberghe's ability to develop a successful method of using existing telegraph lines for simultaneous telephone traffic depended on a result he had obtained (and patented) in 1882 for reducing interference between telegraph lines and separate, but adjacent, tele-

[10]Van Rysselberghe to Secretary of Post Office, August 15 and 16, 1889, E 8376/1891, f8, Post Office Records Office, London.

[11]This paragraph is based on *Electrician* 23 (1889): 584 and 659; and on *Electrical Engineer* 3 (1889): 1; 5 (1890): 62, 102–3, 122; and 6 (1890): 564.

[12]*Electrician* 30 (1893): 418.

phone lines. In his patent[13] of March 1882 he claimed, among other things: "The modification of the telegraphic apparatus . . . to render gradual the emission and the extinction of the telegraphic currents, whereby interference with the telephonic communication is avoided. . . ." His circuits were effectively using either a condenser to ground or a series choke (see fig. 1).[14] He also mentioned the possibility of a varying resistance being coupled to the key, so that a high resistance was inserted at the first pressure on the key, reducing as the depression of the key continued. It is doubtful if this method was ever used in practice. At this stage he was considering only the case of parallel telegraph and telephone wires.

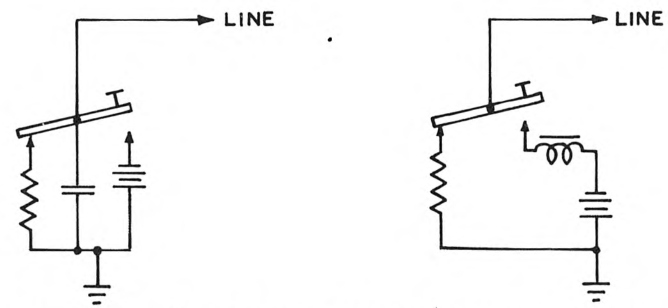

Fig. 1.—Van Rysselberghe's method of smoothing telegraph signal, 1882

[13]British patent no. 1303 of March 17, 1882. See also article in *Electrician* 9 (1882): 176–77. Note that in all cases van Rysselberghe's Belgian patents are dated a week or two earlier than the corresponding British patents.

[14]Figs. 1–8 show various arrangements proposed and used by van Rysselberghe for combining telephone and telegraph circuits on to a common line circuit. The symbol with alternating long and short lines represents a battery, that with two parallel equal lines a condenser (or capacitor), that with a coil represents a choke (or inductor), and that with a zigzag a resistor. The telegraph key, with back and front contacts, is obvious. Blocks are used, where necessary, to represent complete instruments. The important property of a condenser is that it has a capacity for storing electric energy, so that when a steady nonalternating signal is applied to it, it builds up a back voltage due to the stored charge which opposes the applied signal and prevents further current flowing. When an alternating (high-frequency) signal is applied, however, the polarity remains the same for too short a time to enable the back voltage to build up, and thus current flows relatively freely. Thus the effective impedance to the flow of current in a condenser diminishes as the frequency of alternation increases. Speech signals are therefore largely unimpeded while telegraph signals (which alternate only very slowly) are greatly impeded. Chokes have the opposite properties; they can store magnetic energy and pass nonalternating currents freely, impeding low-frequency signals only slightly but high-frequency signals greatly. In this way, a choke in a telegraph circuit removes from the current those high-frequency components which would interfere with telephony, and a condenser in the telephone circuit prevents the low-frequency telegraph signals from affecting the telephone.

Only two months later, van Rysselberghe patented his system of working simultaneous telephone and telegraph traffic on the same single wire, using the principle of smoothing for the telegraph signal.[15] His patent provided for alternative circuit arrangements. What was probably the cheapest circuit is shown in figure 2. This effectively used the telegraph receiver itself as the smoothing device, with a condenser coupling to the telephone circuit. Two other arrangements included in this patent are shown in figure 3. That on the left uses an "induction coil," or transformer (in modern parlance), to provide smoothing and isolation, while the right-hand figure adds the refinement of chokes and a condenser in the key circuit. Evidently, numerous variations of detail are possible, and one which van Rysselberghe developed and favored later is shown in figure 4.

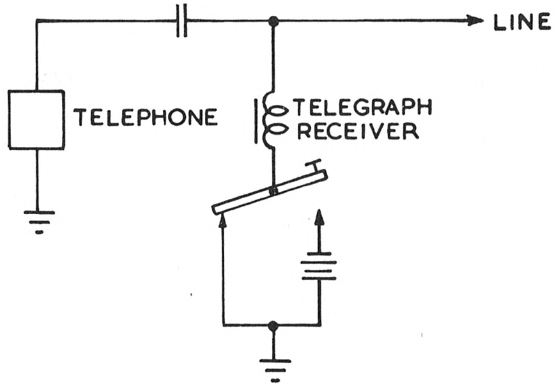

FIG. 2.—Van Rysselberghe's method of combining telephone and telegraph on one wire, 1882.

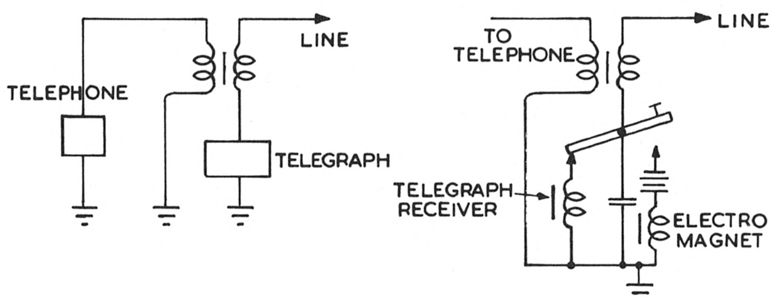

FIG. 3.—Alternative arrangements for combining telephone and telegraph, 1882

[15]British patent no. 2466 of May 24, 1882.

In 1883 Van Rysselberghe proposed arrangements for providing telephone and telegraph circuits on two wires.[16] One group of arrangements comprised two single-wire telegraph circuits with a two-wire telephone circuit superposed. One circuit arrangement for this was a kind of twin version of that of figure 4 obtained by disconnecting the telephone from ground and connecting it via another condenser to the other line. Two other arrangements in this group used transformers—one in the circuit on the left in figure 5 and two on the right.

The other groups of arrangements involved the use, for one circuit, of both line wires in parallel, with a ground return. The idea of superposing a grounded circuit, using both wires, on a loop or metal-

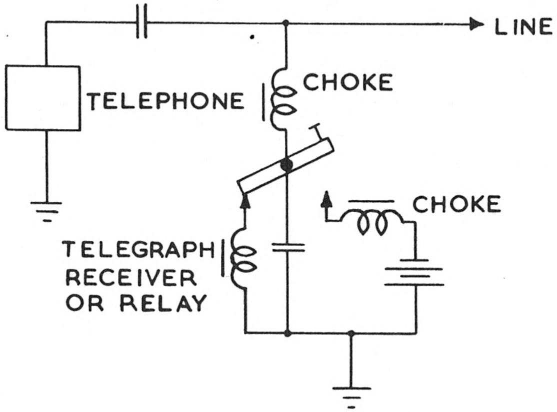

FIG. 4.—Favored circuit, 1885

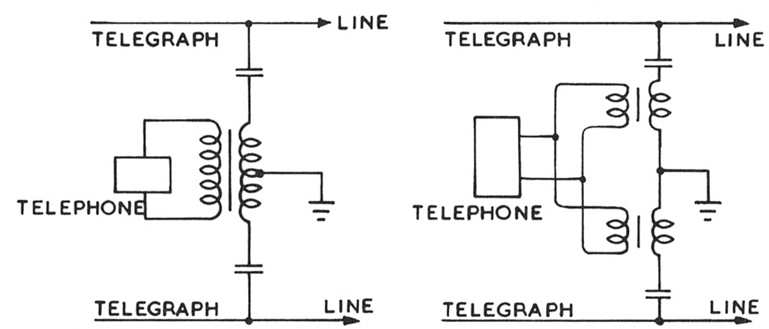

FIG. 5.—Circuits for one two-wire telephone and two single-wire telegraph circuits, 1883, showing use of transformers.

[16]Ibid., no. 3621 of July 24, 1883.

lic circuit had an attraction in that only one circuit was open to induction whereas both would have been if two single-wire circuits had been provided. This system was effectively the basis of what later became known as the "phantom" circuit. One of van Rysselberghe's arrangements provided one metallic telephone circuit and one grounded telegraph circuit as shown in figure 6. Van Rysselberghe made it clear that the circuits of this type required balancing and indicated how balancing elements could be added if necessary. He also indicated that the coupling between the main and superposed circuits might then be small enough to permit the choke function to be dispensed with and resistances used instead.

Many of the above arrangements were repeated in a new patent granted in 1883,[17] but this patent also included a new feature—that of improved filtering or smoothing of the telegraph signal by circuits as shown in figure 7. This kind of circuit is shown in a British textbook of 1928 as the "composite" circuit for combined telephony and telegraphy and is treated as something different from the "van Rysselberghe" system.[18] The composite circuit was apparently then "in use

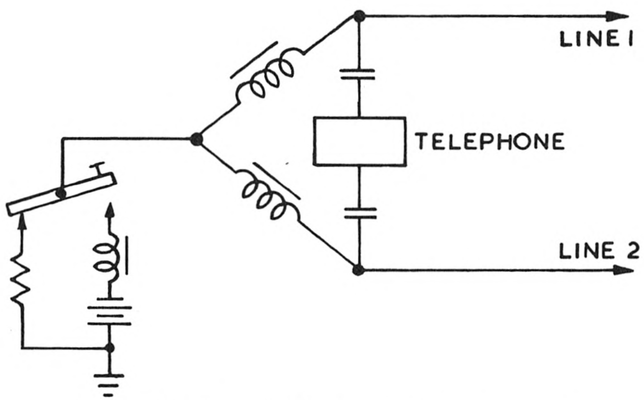

FIG. 6.—Telegraph circuit using two wires in parallel

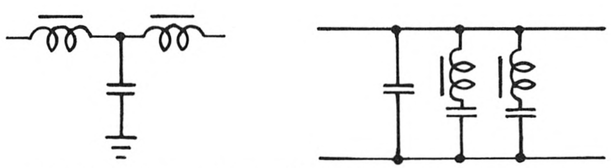

FIG. 7.—Improved smoothing for the telegraph signal

[17]Ibid., no. 5503 of November 23, 1883.

[18]E.g., see A. E. Stone, *A Text Book of Telegraphy* (London, 1928).

in both this country and America." A new British development of "composited telegraph and telephone working" was reported in 1930 without mention of van Rysselberghe, but using his circuits almost exactly, and reporting similar usage in America and Germany.[19] It looks very much as though the "composite" circuit had been reinvented without knowledge of van Rysselberghe's anticipation of it.

Some general accounts of the van Rysselberghe system, including the design of an improved microphone, were published in somewhat clearer terms than the patent specifications, and some of these are readily accessible.[20] The author of two of these, Charles Mourlon, was the licensee and commercial exploiter of the system. The author of another, J. Banneux, was chief engineer of the Belgian Telegraphs, and he alone seems to have recorded how van Rysselberghe dealt with duplex telegraphy. The method employs chokes in the bridge arms (see fig. 8). Note that "duplex" does not mean the same in telegraphy

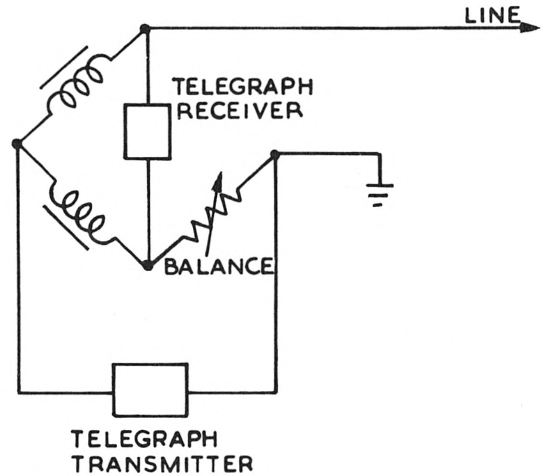

FIG. 8.—Smoothing for duplex telegraphy

[19]J. M. Owen and J. A. S. Martin, *Composited Telegraph and Telephone Working,* Institute of Post Office Electrical Engineers, paper no. 130 (London, 1930). It is worth noting that "composited" telegraph circuits had been used at least as early as 1910 in the United States on the New York–Denver telephone line (see T. Shaw, "Conquest of Distance by Wire Telephony," *Bell System Technical Journal* 23 [1944]: 365), so van Rysselberghe's ideas had eventually been adopted in the United States even if not attributed to him.

[20]J. Banneux, *Télégraphie et téléphonie simultanées par les mêmes fils conducteurs (système F. van Rysselberghe)* (Berne, 1884), copy, inscribed by author to W. H. Preece, in Preece Collection, Post Office Records Office; C. Mourlon, *Système de télégraphie et de téléphonie simultanées . . . de F. van Rysselberghe* (Bruxelles, 1884), copy, carrying Preece's signature, ibid., and "The van Rysselberghe System of Simultaneous Telegraphy and Telephony," *Electrician* 14 (April 11 and 18, 1885): 459–60, 476–77.

as in telephony: a duplex telegraph system is one which permits simultaneous transmission and reception in both directions on the same line and hence requires the use of either a bridge or a differential transformer circuit.

Early Experiments

There was little capability in the 1880s for making objective measurements on telephone lines, neither was the nature of the technical requirement for good speech transmission adequately understood. Thus when van Rysselberghe commenced his investigations early in 1882 he was not only experimenting with his own system, he was experimenting with long-distance telephony in general.

On January 16, 1882, van Rysselberghe tried his first experiment,[21] using only an improved microphone to overcome the inductive interference from neighboring telegraph circuits. As one might expect, he had little success. The line he used was that from Brussels to Antwerp—a 4-mm iron wire that was 45 km long. On February 28, 1882, he tried using condensers in the telegraph circuits, probably according to the diagram in figure 1. This time the route chosen was from the Royal Observatory at Brussels to the Meteorological Station at Ostend (about 125 km). A special wire was run on the telegraph-pole route to carry the experimental telephone traffic. The results were successful, as conversation over the route proved possible. Consequently the experiment was repeated on March 4 in the presence of the director and of the chief engineer of the Belgian Telegraphs and of the director of the Royal Observatory of Brussels. Again he obtained results. Yet another success came a month later, when a telephone circuit from Antwerp to Brussels and back to a different office in Antwerp was set up to include 1.15 km of underground cable in its total length of 89 km.

Van Rysselberghe then turned his attention to simultaneous telephony and telegraphy on the same wire. Although there appears to have been an earlier experiment between Paris and Nancy (353 km) of which no details are available,[22] a definitive experiment was carried out on May 16 and 17, 1882, on the route from Brussels to Paris (335 km). At the Paris end the wire chosen was only one of as many as 400 wires forming a veritable jungle of wire in the vicinity. Although it is not specifically recorded, presumably all the telegraph terminal instruments were fitted with a smoothing circuit (then called an anti-induction device). Since it was during the opening hours of the telegraph offices, speech and telegrams were transmitted simultaneously over the one wire while full telegraph traffic was being carried on all the other lines. The results were excellent and were testified to by an independent observer.[23] We may call this a resounding success, for the press of France and Belgium now asked that the governments take the initiative in providing their countries with a complete long-distance telephone system. On May 31, three Belgian government ministers attended additional successful tests held between Brussels, Ghent, and Ostend. These transmissions succeeded in spite of the fact that only the worst of the interfering telegraph lines had been fitted with anti-induction devices. Indeed, the Brussels–Ghent line was soon used for regular telephonic service, transmitting parliamentary debates and Exchange rates for printing, while the telegraph channel on the same wire was transmitting telemeteorograph signals from the observatory at Ostend.

On June 9, 1882, the van Rysselberghe system achieved an even more impressive success by transmitting over the existing submarine cable from Ostend to Dover. M. Bourdeaux, engineer of the Submarine Telegraph Company, witnessed the experiment at Dover, and M. Banneux was present at Ostend. Conversation from Brussels as well as from Ostend was well received, and to prove it the experimenter at Dover wrote it down and retransmitted it by telegraph back over the same wire to the other end. This was claimed to be the first success in speaking between Belgium and England. It involved 100 km of submarine cable together with 125 km of aerial wire when extended to Brussels.

The last formal experiment of the series occurred on October 7, 1882, on a single-wire line connecting Antwerp, Brussels, and Ostend. It was carried out in the presence at Brussels of the Minister of Public Works, the U.S. resident minister who had been asked to report to his government on the system, and several other senior officials. With Morse, Hughes, and telemeteorograph signals on the same line as well as on adjacent lines, the three telephone stations carried on their conversations with ease. The minister was impressed.

Extent of Use of the System

Following the success of the experiments of 1882, the Belgian government naturally had to consider whether its proposed program of

[21]The best source of information on van Rysselberghe's experiments is Mourlon, *Système de télégraphie.*

[22]*Electrician* 9 (June 17, 1882): 98.

[23]F. Géraldy (editor of the journal), *La Lumière électrique* (Paris) (May 27, 1882), pp. 499–500.

construction of 600 km of new telephone line ought not be replaced by the much cheaper plan of fitting existing telegraph lines with the van Rysselberghe system of simultaneous telephony and telegraphy—at an estimated cost of only 150,000 francs compared with 3 million francs. The cheaper proposition naturally won. On December 14, 1883, the minister of public works approved an arrangement whereby Messrs. Mourlon et Cie. of Brussels undertook to provide all the material necessary for equipping the whole Belgian telegraph network—30,000 km—for simultaneous telephony.

The new service was inaugurated on September 1, 1884, by a rather special, and, one would have thought, risky demonstration. A musical concert at the Waux Hall in Brussels was relayed from six microphones of van Rysselberghe's design in the concert hall, over a van Rysselberghe telephone line, to listeners in Antwerp. According to contemporary reports the results were—fortunately—excellent: "Non seulement les morceaux d'ensemble étaient reproduits avec la plus grand clarté mais le solo de violon exécuté par M. Hermann sur la méditation de Gounod a pu être entendu á Anvers sans qu'aucun détail de l'exécution ait pu échapper aux auditeurs."[24] Moreover, the music did not interfere with the telegraphs, which were busy the whole time.

Expansion of the telephone network in Belgium proceeded quite rapidly, and by mid-1887 there were 7,206 km of wire over which simultaneous telephony and telegraphy were operated, together with a mere 260 km of telephony-only lines.[25]

Other countries were quick to take advantage of the van Rysselberghe system. By mid-1887, lines had been opened in Europe as follows. Holland: Amsterdam–Haarlem, October 1883 (i.e., nearly a year before the first commercial service in Belgium). France: Rouen–Havre, January 1885—Rouen–Louviers, Paris–Rheims, Paris–Rouen, Paris–Havre, Paris–Lille, Paris–Marseilles, also international line Paris–Brussels; total 4,045 km (there were also 420 km of line used for telephony only). Germany: Berlin–Halle, Berlin–Stettin, Berlin–Dessau, Berlin–Oranienburg, Breslau–Beuthen, Munich–Augsburg, Nuremberg–Bamberg, Stettin–Heilbron, Stuttgart–Boeblingen, Stuttgart–Ulm, Stuttgart–Friedrichschafen; total 2,512 km. Austria: Vienna–Brun, 288 km. Switzerland: Geneva–Lausanne (three wires by different routes), Lausanne–Vevey, Zürich–Mannendorf, Bâle–Zürich; total 536 km. Spain: Madrid–Burgos–Valencia–Granada, 840 km. Portugal: Lisbon–Oporto–Cintra. The total extent of van Rysselberghe lines in Europe was about 17,000 km. Another 5,050 km of line was projected. Note that all of these figures relate to the length of single-wire telegraph circuits utilized; most of the telephone circuits were of metallic-loop type using two such telegraph wires.

The van Rysselberghe system was applied also in South America. "Distinct" conversation was achieved on the following routes:[26] Buenos Aires–Santa Fé, 500 km; Buenos Aires–Rosario, 350 km; Santa Fé–Martin Garcia, 570 km; and some others.

Later, in 1888, the system was applied to the Buenos Aires–Montevideo submarine cable (50 km).[27] It was also used to some extent in Brazil, Venezuela, and Mexico and appeared in China[28] and Japan.[29]

* * *

Reference has already been made to van Rysselberghe's experiments in the United States, during the winter of 1885–86. His report on these was published soon afterwards.[30] It is on the whole a careful and lucid document but shows that he had a very real enthusiasm which, no doubt, was the basis of his success in enlisting the cooperation of the senior officials of the telegraph companies. He was allowed to fit his equipment on telegraph routes as shown in figure 9, and his trials of speech transmission were made with the lines simultaneously carrying their normal telegraph traffic. His results are summarized in table 1.

It must be emphasized that these experiments used special microphones and receivers designed by van Rysselberghe and were made under ideal terminal conditions (i.e., there was no switchboard or local line). Clearly, the limit of acceptable telephony, under these special conditions, was about 300 miles on iron wires of 4–5-mm diameter and on copper wires of 2.1 mm. It was about 600 miles on copper wires of 2.7 mm. On the compound wire, comprising a 3-mm steel core with a 1.5-mm layer of copper around it, the limit was not reached at 1,000 miles.

The range of 1,000 miles was at that time an achievement almost beyond belief. It had been achieved on a telegraph line in normal

[24] *Le Moniteur belge* (September 1884). English translation: Not only were the orchestral pieces reproduced with the greatest clarity, but the violin sole executed by M. Hermann, Gounod's "Meditation," could be heard in Antwerp without any detail of his execution being missed by the listeners.

[25] *Electrician* 19 (September 2, 1887): 358–59.

[26] Ibid., 17 (July 2, 1886): 145.

[27] Ibid., 22 (December 7, 1888): 124.

[28] *Electrical Engineer* 4 (October 18, 1889): 301.

[29] *Electrician* 19 (July 1, 1887): 153.

[30] Report by F. van Rysselberghe, *L'Electricien* 10 (1886): 307–13.

service by the use of van Rysselberghe's special system. Not surprisingly, he was excited about it and optimistically predicted that transcontinental telephony was now feasible. However, it would be thirty years before this was achieved. Heaviside's theory of telephone transmission had not yet been published, and van Rysselberghe had no means of making correct extrapolations from his results. It is, however, very puzzling why there was no commercial exploitation of his results in the United States; commercial telephony between New York and Chicago was not provided until 1892. No doubt the separation of telephony and telegraphy under the Bell System and Western

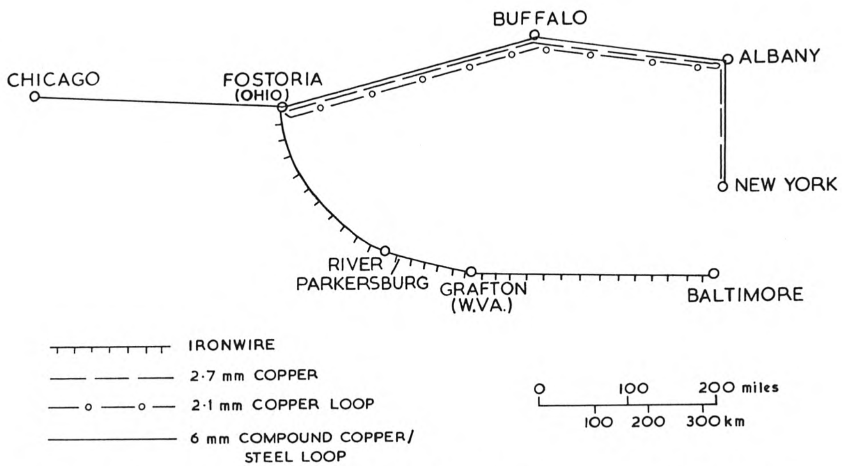

FIG. 9.—Routes used for van Rysselberghe's experiments in the United States

TABLE 1

SUMMARY OF VAN RYSSELBERGHE'S EXPERIMENTS IN THE UNITED STATES

Circuit	Length (Miles)	Wire Type/Diameter (mm)		Result
1. Grafton–Parkersburg	104	Iron	4	Good
2. Grafton–Parkersburg	104	Copper	2.7	Splendid
3. River–Fostoria	229	Iron	5	Fair
4. Grafton–Fostoria	323	Iron	4.5	Unsatisfactory
5. Baltimore–Fostoria	620	Iron	4.5	Nothing heard
6. Fostoria–New York	730	Copper	2.7	Very weak
7. Fostoria–Albany	585	Copper	2.7	Good
8. Fostoria–Albany	585	Copper	2.1	Very weak
9. Fostoria–Buffalo	300	Copper	2.1	Good
10. New York–Chicago	1010	Compound	6	Excellent

Union, respectively, as van Rysselberghe himself pointed out,[31] made exploitation of simultaneous telephony and telegraphy difficult, and the long-lines program of the Bell System (under the American Telephone and Telegraph Company) had not yet got under way. But the way in which the American technical press ignored van Rysselberghe completely in regard to his U.S. experiments, and to a large extent over the whole period from 1882, is surprising and not readily explained. In British and European journals van Rysselberghe's work was repeatedly and frequently referred to in great detail, but I can find only desultory references to it in the *Electrical Review* (New York), although this journal frequently and fully reported other European workers and reprinted their articles.

Criticisms of the van Rysselberghe System

It was very noticeable that the British authorities (both companies and state) were practically alone in not even trying the van Rysselberghe system. There was, of course, no incentive for the telephone companies to do so, for the telegraph lines were all owned and operated by the Post Office and the companies had either to erect their own interurban telephone lines or, alternatively, to lease lines from the Post Office, which also provided a few long-distance telephone lines. Thus the van Rysselberghe system could be adopted in Britain only if the Post Office would accept it. This it would not do. W. H. Preece, electrician to the Post Office, explained the reason in his lecture to the Society of Telegraph Engineers in 1886.[32] While he accepted the fact that the system worked well when the telegraph traffic was on the Morse or Hughes systems (which had a speed of fifteen to twenty words per minute), he could not accept the idea that it would work with the Wheatstone automatic system, which was widely used in Britain and had a speed of 300 words per minute, or even more. He took the view that van Rysselberghe's "anti-inductors" would prevent telegraph working at this speed and slow the Wheatstone system down to under 150 words per minute. Preece also contended that van Rysselberghe's system used too many components.

The latter argument was very questionable, but the former was sound. Allowing that a telegraph signal needs the fundamental and third harmonic of its repetition rate as a minimum for adequate transmission, the hand-worked Morse system requires a pass-band only up to around 40 Hz, whereas the Wheatstone automatic system

[31]At a meeting of the Society of Telegraph Engineers in London, May 13, 1886 (*Journal of the Society of Telegraph Engineers* 15 [1886]: 293).

[32]Ibid., pp. 274–303.

requires up to at least 500 Hz. A proper separation of speech and telegraph signals is evidently impossible in the latter case. So on the main routes in Britain it was not technically feasible to use the van Rysselberghe system. One would have thought its use to have been attractive on outlying routes, but it has to be appreciated that the British government was anxious to protect its telegraph system from the competition of the telephone and had, in consequence, a marked antitelephone policy.

Banneux, the French engineer whose booklet of 1884 has already been cited, was aware of the technical objection discussed above, for he refers to it as a problem requiring investigation. He also states that the van Rysselberghe system was tried in France with high-speed Hughes telegraphy, running at "150 tours de chariot," with complete success. Presumably "150 tours" means 150 rpm (i.e., 2.5 rps). The Hughes system was a synchronous type-printing system using keyboard and printer.[33] It transmitted a single short pulse for each letter, the letters being distinguished by the time of occurrence of the pulse in each turn of the chariot. With twenty-eight symbols and 2.5 rps, the cutoff frequency for the telegraph signal would have to be at least 200 Hz, and the suppression above this would have to be quite good to avoid interference with the speech channel.

* * *

Where the van Rysselberghe system had been applied the operating authorities seemed reasonably satisfied with it at first. However, some criticism and controversy arose There were difficulties with the van Rysselberghe system in Switzerland, it would seem, for controversy arose in 1888. The *Electrical Engineer* reported in an editorial that the system

> has not hitherto been a success in Switzerland, and the results there obtained render it questionable whether it has in reality proved successful elsewhere. The system was adopted experimentally by the Swiss Government on the Bâle–Zürich line, and the results are stated to have been so unfavourable that the idea of applying it to other lines has been relinquished, and, in spite of the large expense involved, it has been decided to establish special lines for inter-urban traffic. Moreover, the establishment of this means of communication between Bâle and Zürich, in substitution for the van Rysselberghe arrangements, is under consideration.[34]

[33]For full description, see T. E. Herbert, *Telegraphy* (London, 1907), pp. 370 ff.
[34]*Electrical Engineer* 1 (March 30, 1888): 290.

The *Electrician* knew all along that

> its application must be limited to circuits on which the telegraph service is not (as a rule) of a pressing character. . . . the very considerable success which it has attained abroad is simply a proof of the comparatively low telegraphic development of the countries where it is found useful. . . . Dr. Rothen (Director of the Swiss Telegraphs) . . . says that although the ordinary Morse signals do not suffer, the Hughes printing apparatus is often deranged. . . . From the telephonic point of view . . . the transmission is feeble and the extinction of the telegraphic signals is obtained only in theory.[35]

Messrs Mourlon et Cie., of Brussels, the licensees of the van Rysselberghe patents and manufacturers of his equipment, took exception to the criticisms which the *Electrical Engineer* had reported (which had been published first in the *Bulletin international de l'électricité* for March 26, 1888) and stated, "We do not know where you may have got that information from, since it is utterly wrong. . . . the two telephonic communications between Basle and Zurich are working regularly. . . . it [the van Rysselberghe system] is not on trial merely, as you seem to think. . . . Its success had long ago been proved in Switzerland. . . ."[36]

Another controversy arose in relation to the Paris–Brussels international telephone lines. This is believed to have been the world's first international telephone system, and it worked on the van Rysselberghe system from its inception. The convention between France and Belgium was signed in late November 1886, and the line was successfully inaugurated on January 29, 1887, being opened to the public on February 24, with special connections between the Bourses at Brussels and Paris.[37]

As iron wires had not been found satisfactory for telephony over the longer distances, this line was constructed of silicon-bronze wire loop, each wire 3 mm in diameter, weighing 223 pounds per mile.[38] Such wire was stronger than pure copper, although in fact this line allegedly failed to stand up to serious gales the next winter.[39] Simultaneous telegraphy was provided along with the telephony by the van

[35]*Electrician* 21 (May 18, 1888): 33.
[36]*Bulletin international de l'électricité* (April 9, 1888), reprinted in *Electrical Engineer* 1 (April 20, 1888): 374.
[37]*Electrical Review* (London) 19 (1886): 527 and 20 (1887): 110, 157, 182.
[38]A. Berthon, *Bulletin de la Société Internationale des Electriciens* 4 (1887): 191; summary in *Journal of the Society of Telegraphic Engineers* 16 (1887): 463.
[39]*Electrician* 19 (1887): 529; the damage was, however, denied by the manufacturers of the wire (see ibid., 20 [1887]: 26).

Rysselberghe system, a Hughes printing telegraph being worked on *each* of the two wires.[40]

The line was a great success, with an average of eighteen to twenty-three telephone calls per hour.[41] In the light of this traffic, it was proposed to provide a second line and also to provide for subscribers to speak over the line from their own premises instead of having to go to special call offices. Special arrangements were needed for this as, in addition to any difficulties due to additional interference, the local lines were single wire and required special apparatus to enable them to be coupled to the metallic-loop long-distance line. Provision was made for the line to be extended to Amsterdam.[42]

The second line was provided quite quickly, being completed by the end of January 1888.[43] It did not follow the same route as the first line, as can be seen from the map in figure 10, but it was erected on an existing pole route which carried telegraph circuits but no other telephone circuits.[44] Why a different route was chosen is not known for certain; it was probably because of a fear of cross talk. The lines were provided with regular transpositions to neutralize interference from parallel telegraph lines and other sources, but it was perhaps not felt at that time that making the transpositions of different periodic lengths would be effective in reducing cross talk between parallel telephone lines. Alternatively, it may have been to provide greater reliability by avoiding the breakdown of both lines simultaneously. It is almost certain that the van Rysselberghe system was used also on the second line.

The van Rysselberghe system was obviously a success on these routes—at least for some years. When W. H. Preece of the British Post Office visited Paris in September 1889 he was not only shown the line (referred to in the singular) in operation but also allowed to make some experiments upon it. His report states: "I found that while the Hughes apparatus was not fitted with the van Rysselberghe anti-inductor, it was impossible to carry on conversation owing to the distressing sounds made, but when the van Rysselberghe anti-inductor was connected up then the noises were reduced so low that they were virtually imperceptible. The conclusion left on my mind by this experiment is unmistakably that it is quite practicable to construct

[40]Report by W. H. Preece, September 6, 1889, E 8376/1891, f12, Post Office Records Office, London.

[41]*Electrical Review* (London) 20 (1887): 358.

[42]Ibid., p. 383.

[43]*Electrician* 20 (1888): 281.

[44]*Electrical Review* (London) 20 (1887): 601.

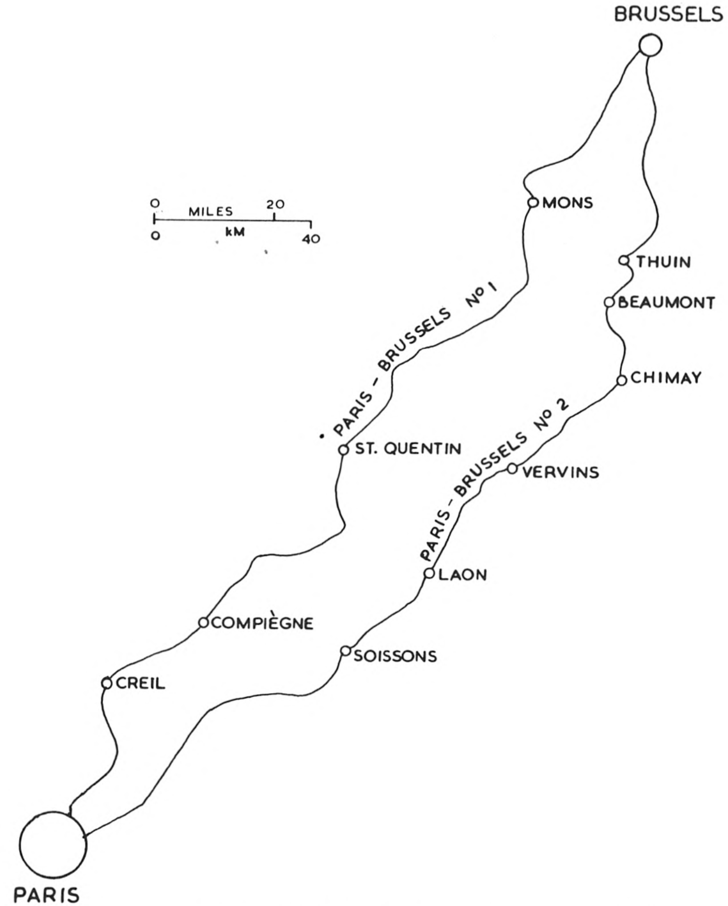

FIG. 10.—Routes of Paris–Brussels telephone lines, 1887–88

a telephonic circuit between London and Paris, and work upon it at the same time telegraphically with Hughes apparatus."[45]

Bearing in mind that Preece was notoriously skeptical of van Rysselberghe's system, this was praise indeed. Yet less than a year later, on another visit to Paris in August 1890, Preece found that the French had turned against the van Rysselberghe system. He reported:

> I am sorry to say that the results of experience of simultaneous working with Hughes and telephones on the same wires appears to be unsatisfactory to the van Rysselberghe system. It was re-

[45]Report by W. H. Preece, September 6, 1889, E 8376/1891, f12, Post Office Records Office, London.

ported to me that they found it was difficult, if not impossible, to work Hughes simultaneously over a greater distance than 130 miles, and I was surprised to learn that between Paris and Brussels the van Rysselberghe system has failed. It was working so well when I was in Paris last year that I cannot quite understand the reason of the failure; and I propose with the Secretary's permission to proceed to Brussels on Friday night to have a conference with the Belgian authorities on the subject.[46]

Unfortunately, no record of his discussions in Brussels has been found. The French obviously failed to satisfy Preece, and it is quite possible that other than purely technical considerations were involved, for the Paris–Marseilles telephone route, which was opened in 1891, used a different system of simultaneous telegraphy and telephony—that invented by Picard (believed to have been a Frenchman).[47]

In spite of these setbacks, the van Rysselberghe system was still working in March 1891 on the Paris–Brussels route, which ran alongside the new London–Paris route for many miles from Paris to Creil.[48] Telephone traffic between Paris and Brussels evidently continued to expand for the time allowed per call was in 1891 reduced from five to three minutes,[49] and a third line was provided in 1892.[50] But it is not known whether it had simultaneous telegraphy. Although it is difficult to establish the truth, it is obvious that the van Rysselberghe system often failed to give complete satisfaction. The line in Austria, between Vienna and Brun, was given up in favor of a separate telephone line,[51] and the Dutch authorities were apparently not pleased with the system.[52]

* * *

Details of how the van Rysselberghe system fared in the half-century following the developments described above have not been established. It evidently remained in use for a long time as it was still described as a current system in 1928.[53] It was also used, under the

[46]W. H. Preece to Secretary to Post Office, August 25, 1890, E 8376/1891, f20, Post Office Records Office, London.

[47]*Electrical Engineer* 8 (1891): 461.

[48]Report by H. R. Kempe and W. Brown to Preece, April 6, 1891, E 5357/1891, Post Office Records Office, London.

[49]*The Times* (March 24, 1891), p. 5.

[50]*Electrician* 28 (1892): 532.

[51]*Electrical Engineer* 5 (February 14, 1890): 122.

[52]*Electrician* 21 (June 8, 1888): 135.

[53]Stone (n. 18 above).

name "sub-audio telegraphy," on many submarine cables until after the Second World War,[54] although, of course, much more sophisticated filters were employed by then.

The growth of the modern communication network, with amplified lines and submarine repeaters together with radio links and the universal use of the teleprinter with carrier channels, has led to the general disappearance of systems such as that of van Rysselberghe.

Before leaving the subject, it is worth mentioning that later 19th-century inventors claimed improved systems for simultaneous telephony and telegraphy, notably Langdon-Davis with his "phonopore,"[55] Picard,[56] and von Demetzky.[57] It is believed, however, that no principles not already described by van Rysselberghe were involved.

The Question of Novelty

There can be little doubt that van Rysselberghe was the first to apply the concept of simultaneous telephony and telegraphy on the same wires with practical success, and to the best of my knowledge his priority as inventor of the system was never legally challenged. But it is of some historical importance to establish whether he was indeed, in a scientific or engineering sense, the first and true inventor of the system. I am satisfied that he was.

There are two principal elements in van Rysselberghe's system: (*a*) the smoothing of the telegraph signals to reduce the interfering components, (*b*) the superposition of the telephone signals on the telegraph line. Regarding *a,* I can find no anticipatory reference to the use of chokes or condensers to reduce the interference from telegraph to telephone circuits, but the idea of using chokes to reduce the liability of a telegraph signal to interfere with other *telegraph* signals was put forward by D. E. Hughes before 1879. He seems to have understood the nature of the problem quite thoroughly, and it is worth explaining his work on this matter.

Long before telephony became a commercial proposition, trouble was being experienced by "induction" on telegraph routes where several wires ran parallel along the same line of poles. Hughes was en-

[54]B. S. Cohen, *Handbook of Telecommunication* (London, 1947).

[55]*Electrician* 22 (April 5, 1889): 614–15, *Electrical Engineer* 8 (1891): 36, 97, and 9 (1892): 371; D. G. Tucker, "Phonopore and phonoplex," *Proceedings of the Institution of Electrical Engineers* 121 (1974): 1603–8.

[56]*Electrical Engineer* 8 (1891): 461.

[57]Ibid., 11 (1893): 497.

gaged by the French telegraph administration to investigate the problem.[58] He found that smoothing by means of an electromagnet was a satisfactory solution for low-speed signaling but not for higher speeds, where his choke destroyed the wanted signals too. The obvious solution of using a choke with lower inductance was apparently not tried out. He reached the conclusion that the best solution was to use double-wire or loop circuits with a twist rather than single wires with earth return.[59] But as this was an expensive and therefore unattractive solution, in 1879 he offered an invention of his own. This was to insert, at the transmitting station of a group of wires all transmitting in the same direction, a group of coupled coils so adjusted that the induction between them was the same as that of the lines themselves. The transmitting key of each line had extra contacts which reversed the terminal connections of the coil in that line at the instant of transmission. The induction into the other lines from the coil was thus made opposite to that from the line itself, thus canceling out the induction completely. This was claimed to work well in laboratory demonstrations but was probably not taken up in practice. Possibly the inconvenience of having to work all lines on a route in the same direction for given periods proved an insuperable objection.

Whether or not van Rysselberghe knew of Hughes's work is not known, but the extension of the idea of using a choke, to prevent interference from telegraph to *telephone* signals, is an inventive step, even if a simple one, and there is little doubt that van Rysselberghe was the first to use chokes in this way. His development of more complex choke-condenser circuits to improve the suppression of interference was a quite original step. Moreover, he seemed to think of the function of the choke circuit as removing the vibratory components of the telegraph signal (see his patent of July 24, 1883), that is, those which were of the same nature as the telephone signal, and so he seemed to have something of the concept of low- and high-pass filtration.

As regards element *b,* the idea of superposing a.c. channels (but *telegraph* channels using a keyed vibratory current) on a d.c. telegraph system was quite old (e.g., Bell's and Gray's well-known multiplex telegraph systems among many others). Indeed, Varley in 1870 had clearly described the requirements of such a system in terms of frequency separation of channels and had used chokes and condensers

[58]D. E. Hughes, "Experimental Researches into Means of Preventing Induction upon Lateral Wires," *Journal of the Society of Telegraph Engineers* 8 (1879): 163–76; also discussion, pp. 318–26.

[59]Alexander Graham Bell had patented this in 1877 (e.g., British patent 4341 of that year) and may have anticipated Hughes.

skillfully.[60] However, while the chokes were used to *isolate* different sections of line from one another for a.c. channels (so that they could terminate at intermediate stations) while passing the d.c. signal straight through, there was no use of a choke to *suppress interference* from the d.c. channel to the a.c. channels. Thus, once again, while it was perhaps only a small step from Varley's system to van Rysselberghe's, it does seem clear that van Rysselberghe's scheme of simultaneous telephony and telegraphy was a genuine invention.

It needs also to be mentioned that Black and Roseburgh in 1879 had described the superposition of a telephone channel on a d.c. telegraph system by means of a resistive or capacitive tap,[61] but they disclosed no concept of smoothing or filtration in either channel and no provision for removing or reducing mutual interference.

It seems, therefore, that there were elements of genuine novelty in all the main aspects of van Rysselberghe's patents. In short, his system can be said to have been new, and it appears to have been universally accepted as such.

* * *

What sort of inventor was van Rysselberghe? The evidence of his patent specifications (which, although prepared by a patent agent or attorney, would undoubtedly represent his own thinking) is that he was empirical in his approach. He showed understanding of qualitative aspects of electromagnetism, frequency spectra, circuit arrangements, etc., which stood him in good stead when he was concerned with lumped circuits and ordinary signals.[62] His development of the circuits shown in figure 7 demonstrates this: these circuits can reasonably be regarded as what became later known as electric-wave filters and for their time were quite sophisticated. It seems certain, however, that he had little understanding of the properties of continuous lines. A very valuable source of evidence for this statement is his report on his experiments in the United States, already cited. In this report he demonstrates a lack of understanding of transmission principles and of the relationship between the capacitance of a single-wire line with earth return and that of a metallic-loop line using the same gauge and type of conductor. He thought the latter would

[60]C. F. Varley, British patent no. 1044 of April 8, 1870.

[61]G. Black and A. M. Rosebrugh, British patent no. 1477 of April 16, 1879.

[62]Quantitative analysis of his system had to wait until the work of K. Berger (*Das Gleichzeitige Telegraphieren und Fernsprechen und das Mehrfachfernsprechen* [Braunschweig, 1910]) and J. G. Hill ("Phantom Telephone Circuits, and Combined Telegraph and Telephone Circuits, Worked at Audio Frequencies," *Journal of the Institution of Electrical Engineers* [London] 60 [1922]: 675–705, esp. 676–80).

be twice the former, whereas in practice the two capacitances are much the same. In these matters he showed no more ignorance than most of his contemporaries. Even four to five years later, after much of Heaviside's work on the subject had been published, W. H. Preece, electrician to the British Post Office, made a mistake of the same magnitude regarding line capacitance, thinking the loop capacitance would be half that of a single wire; and Preece's condemnation of Heaviside's views on the significance of inductance has become notorious.

Although it is clear that van Rysselberghe did not have a mathematical approach to his work in communications, his success makes it certain that he had a practical flair of high order.

* * *

François van Rysselberghe made an important contribution to the development of telephony. Whether he realized that the problem his system solved was merely a temporary one we do not know. At a time when the established demand for long-distance telephony was small, he made it economically possible in a situation of low density of lines by enabling telephone circuits to be used over existing single-wire telegraph lines without unacceptable mutual interference between telephone and telegraph. When traffic grew large and pole routes carried a high density of lines, cross talk between telephone circuits would become intolerable, and metallic-loop circuits with systematic transpositions were the only solution. Even in this situation, however, the van Rysselberghe system retained an economic attraction in enabling telegraphs to be used over the telephone wires as in the case of the Paris–Brussels lines. However, the extraordinarily rapid expansion of telephony coupled with relatively static telegraph traffic led to the rapid decline of the van Rysselberghe system. It served its purpose over a short critical period, less than a decade, and accelerated long-distance telephony (except in the United States and Britain where special factors applied) by probably some five years. Van Rysselberghe was a great and influential man in his time, but he has left little mark on the present. Perhaps that is why he has been so generally forgotten.