A reproduction of an experimental tuned transmitter circuit as described in patent no. 7777, issued to Guglielmo Marconi and the Marconi's Wireless Telegraph Company Ltd., 1932, inv. IGB 002137

This reproduction of an experimental oscillation transformer for transmitting apparatus, the so-called 'jigger', is made up of a square wooden frame, into which are fixed a Leyden jar (an early type of electrical capacitor invented in the Netherlands in the mid-eighteenth century which was still in use at the end of the nineteenth century) and a spark gap or a brass sphere electrical oscillator. The jar, which was used to condense the energy supplied by a battery (not present), was connected to the spark gap and to the wire wound around the frame. The jigger served to connect inductively the circuit of the spark gap generating electromagnetic waves (the radio signal) to the earthed antenna circuit designed to transmit them (Fleming 1906, 44-5; Hong 2001, 62). The type of waves transmitted varied according to its characteristics (the length of the primary and secondary wires, the number of coils). A receiver equipped with an oscillation transformer tuned to the jigger of the transmitter had the capacity to selectively receive wireless signals. The artefact features a wall-mounted pedestal with a back panel at the top of which is attached a circular celluloid plate bearing the no. 4, similar to those found on other Marconi relics (Casonato, Spada, *infra*). It was given to MUST in 1955 by SIRM, one of the Marconi Company's Italian subsidiaries. MUST houses another identical object (IGB-009882), currently on display in the Marconi exhibition area, but it has no plate markings. In his 1932 diary George Kemp, one of Marconi's assistant, lists the objects which were reproduced in four copies for the 1933 Chicago World's Fair. The exhibition catalogue *A Century of Progress* mentions the copy of an "Experimental tuned transmitter" (OBL MS Marconi 88. G. Kemp's Diary, 16/12/1932). The 'Marconi's Wireless Telegraph Company' brass plate is also present on an identical replica kept in the Oxford HSM (inv. 64464). Four screw holes and the outline of a missing plate are visible at the bottom of the artefact in the photograph. These clues lead us to believe that it is one of the display models produced for the Chicago World's Fair, or at the very least, as MWTC display material.

The Jigger. Probing the Fieldwork of Marconi’s Assistants (1897-1901)

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> At that time wireless was not recognized as a definite branch of electrical engineering, and engineering opinion was dubious as to its future, but in the Marconi Company, and amid the buoyant atmosphere which surrounded its chief, no one had time to worry about trifles such as the prospects; we went all out to master the problems of the moment, and the future had to take care of itself.
> Henry Dowsett, “How I Began”. *Daily News*, 27 August 1927

In 1900 Marconi filed the application for the 7777 patent, which was of fundamental importance to the development of his system of wireless telegraphy, both from a commercial and a technological perspective. The innovations described in that patent constituted an important step forward in the attempt to achieve the crucial goal of tuned transmission, while at the same time enabling a considerable increase in communication distances. The device at the heart of this innovation was the jigger, a frequency transformer, which in both its prototype and commercial versions often features among the most iconic artefacts displayed in Marconian exhibitions.[1]

Jiggers have a long and complex history, which began as early as 1898, during the course of which their characteristics and operational usage were gradually modified and improved.

1 Jigger was one of the colloquial and generic terms used in the second half of the nineteenth century by English engineers and technicians to refer to both machines and machine components. In one of H.G. Wells’ science-fiction short stories, “In the Abyss”, which features Victorian engineers and technicians as protagonists, the inventor of a deep-sea submersible describes it as a jigger (Wells 1897, 73).

This step-by-step process, which emerges thanks to the detailed examination of the material characteristics of these artefacts and the related documentation, provides an opportunity to analyse the distinctive aspects of Marconi's experimental approach and the environments in which the research was carried out. In particular, the case of the jigger allows us to highlight and draw attention to the role of the group of technicians from Marconi Wireless Telegraph Company (MWTC), whom Marconi himself described as his assistants.

Some of Marconi's collaborators are well known and often referred to in the literature on the history of wireless telegraphy: his loyal attendant George Kemp, the experimental physicist and electrical technology expert John Ambrose Fleming, who was a long-time consultant for the MTWC, and the company employees who subsequently became renowned in the wireless sector, most notably Charles S. Franklin and Henry J. Round. Nevertheless, very little emerges from the Marconian narrative about the work of other young technicians who were part of that group of assistants. Even when some of the collaborators are mentioned, their contribution towards the development of this new form of communication technology is not examined in detail.[2] Yet the important role played by the assistants is abundantly documented in the company records of the Marconi Archives at the Oxford Bodleian Libraries, and it was repeatedly acknowledged by Marconi himself.

In this essay the artefacts act as an insight into the activity of Marconi's closest collaborators; the purpose is to offer an appreciation of the extent of their involvement in the experimental work of their leader and of their contribution to the success of his system.

1 A Promising But Imperfect System

Only four years after obtaining the first patent, Marconi's wireless telegraphy apparatus succeeded in transmitting over distances long enough to generate interest in potential customers. However, the negotiations for the commercialization of the MWTC equipment stalled as a result of unresolved drawbacks which caused the system to be insufficiently reliable.[3]

The disturbances caused by atmospherics, and above all the interference between stations operating simultaneously, were among the most serious handicaps. Due to these problems, the system was unable to ensure the privacy of communications. In cases where contact had to be established between ships at sea – and between ships and shore stations – for safety information relating to navigation, the reception of messages by whoever had access to wireless apparatus was obviously a positive feature. Nevertheless, when it was a matter of communications whose content was exclusively intended for specific recipients, the lack of selectivity was a serious deterrent. Not surprisingly, communication confidentiality was one of the requirements stipulated by the English army, both by the War Office and the Royal Navy, for the purchase of MTWC equipment.

Faced with negotiations that could not be finalized, Marconi and his company had to focus their efforts not only on extending the range of communications, but also on finding a solution to the selectivity problem. Those efforts were all the more crucial because syntony had

2 A partial exception is the overview on the community of Marconi's assistants emerging from chapter on "The Old Time Engineers" in Baker 1970.

3 Marconi himself described the long series of laborious passages leading up to the 7777 patent in Marconi 1901.

been one of the key features of Oliver Lodge's 1897 patent for a wireless telegraphy device.[4] In fact, not unlike other startup companies based on ground-breaking new technologies, the main activity of the MWTC in its first years of business consisted exclusively in an attempt to improve the system and make it commercially viable.

It was no coincidence that the Royal Navy only decided in July 1900 to order wireless equipment for 26 ships and six land stations when the company announced it had made advances in tuning. It was the first important contract obtained by the MWTC. In 1901 the company began to receive orders for both ship and land station installations; admittedly, sales remained well below the expectations of Marconi and the company shareholders, but those first contracts were the commercially tangible result of the strenuous effort to improve the quality of communication. It was a success that Marconi achieved also thanks to the effort put in by his assistants.

2 The First Assistants

Until the establishment of the company, Marconi had conducted his research with the assistance of staff put at his disposal by the British General Post Office, thanks to the patronage of its Engineer in Chief, William Preece, and the technical personnel of the Royal Engineers. Of particular note was Captain John N.C. Kennedy, appointed in 1897 by his superiors to oversee the Salisbury Plain experiments, who continued to lend his backing and enthusiastic support to Marconi until 1899. Captain Baden F.S. Baden-Powell (brother of Robert, founder of the Scout movement), a pioneer of aviation and an expert in the military use of kites and balloons, taught Marconi how to fly them as an alternative to poles and masts for raising the wires. The assistance provided by the Royal Navy technicians was also considerably valuable, and so was above all the generous support and encouragement offered by Henry Bradwardine Jackson, a Royal Navy captain and a wireless telegraphy pioneer himself.[5]

However, when the MWTC was incorporated in 1897, the General Post Office withdrew its support. At that point, if Marconi was to be able to continue with his experiments, technical staff had to be hired. Henry Jameson Davis, Marconi's cousin and one of the company directors, took charge of their recruitment relying on his contacts in the London engineering community.

Although there was no theory to guide the design of equipment and installations, and it was by no means clear on what scientific principles wireless telegraphy was based, a basic understanding of electrical technology and a sound knowledge of traditional telegraphy instrumentation were among the qualification requirements sought in the selection of employees. It was no coincidence that some of the first technicians were hired on the basis of the skills they had acquired working for telegraph companies or, as in the case of George Kemp, for the General Post Office.

Many of the apparatus components were purchased from London-based manufacturers of electrical equipment, but others had to be adapted to the particular functions required by the system; some, in particular the

4 Oliver Lodge, "Improvements in Syntonized Telegraphy Without Line Wires", UK patent no. 11,575, 1897.

5 Jackson was later to be appointed Director of the Royal Naval War College and Chief of the Admiralty War Staff; he was also First Sea Lord in 1915-16. On his research on wireless telegraphy see Pocock, Garratt 1972. As for Kennedy and Baden-Powell, see respectively "Obituary" 1915 and Pritchard 1956.

coherers, had to be produced with specific characteristics. It is therefore not surprising that one of the first employees was an instrument maker, John Cave, and that because of his expertise in the technique of glass-blowing he was entrusted with the production of coherers.

Among Marconi’s closest collaborators were some young graduates from higher education institutions: in particular Edward Glanville, James Erskine Murray, and Andrew Gray. The first studied physics at Trinity College Dublin, where he had been a student of George Fitzgerald (Sexton 2005); Murray had been a student of Kelvin at Glasgow University and subsequently a researcher at the Cavendish Laboratory in Cambridge (*Proceedings of the Royal Society of Edinburgh* 1928). As for Gray, he had graduated from the Royal Technical College in Glasgow and had then worked at the West India and Panama Telegraph Company (“Andrew Gray, Chief Engineer MWTCo” 1916) **[fig. 1]**. Others were students who had attended physics and electrical engineering courses offered by London-based technical schools. Paradoxically, a good number of them had been students of Silvanus Thompson, professor of electrical engineering and principal of Finsbury College, who was a staunch opponent of Marconi. However it must be pointed out to his credit that Thompson was one of the best teachers of that new discipline, not only for his skills as a lecturer and demonstrator, but also as a source of inspiration for the professional careers of his students (Arapostathis, Gooday, Ash 2021).

It is worth noting that an assistantship was not a formally recognised job position within the MWTC employment structure. The task of the first employees was to collaborate with Marconi, who was the technical director of the company, in his experimental work. The qualification as assistants became the informal occupational description of the members of that group of recruits.[6] When their number gradually increased – initially operators for the growing number of wireless telegraphy stations, then from the end of 1898 workers for the Chelmsford factory – a selection process was put in place to single out those with not only the skills, but also the stamina and determination required in order to keep up with the daunting task of supporting Marconi’s extraordinarily intense research effort.

The common characteristic of almost all the assistants, with the exception of Kemp and Cave, was definitely their young age; it was also their willingness to participate in an adventure at the edge of technological impossibility. In order to play that role it was necessary to learn from practice, even leaving aside some of the knowledge acquired in their previous electrical engineering experience. The premise was clear: the truly relevant instruction was gained working side by side with Marconi at the experimental stations where the wireless telegraphy equipment was assembled and tested. Training consisted of learning not only to set up and use the apparatus, but also to build some of the components: relays, capacitors, resistors, aerials and also coherers.

Marconi’s goal, therefore, was not only to instruct competent wireless operators, but also to enable them to acquire the practical know-how and experience necessary to contribute to the improvement of the new technology, essentially by trial and error. The way in which research was carried out had a particular characteristic: experiments were conducted using instruments and apparatus designed for field tests. The functioning of the entire transmitting and receiving apparatus, including the power supply devices and antennas, could only be examined in those operating conditions. Therefore the laboratories were the wireless stations, both the permanent ones built by the MWTC along the British coast, and

6 The term ‘assistant’ appears not only in public and private Marconi publications, but also informally in the MWTC documents referring to staff and their movements: OBL MSS Marconi 639-40; OBL MS 654.

Figure 1 Staff of the Marconi Wireless Telegraph Company, 1898. From top to bottom, left to right: A.A. Cahen, J. Erskine Murray, P.W. Paget, G.S. Kemp, T. Bowden, G.L. Bullocke, G. Marconi, H. Jameson-Davis, W.W. Bradfield, W.R. Elliot, E.E. Glanville, C.E. Rickard, J. Cave; H.W. Allen (secretary of the MWTC). George Kemp, "Extracts from Diaries, 1897-1898", OBL Marconi Archive, MS Marconi 89

the temporary ones set up on land and on ships, for the purposes of demonstration to public and private agencies interested in the new communication technology.

To carry out this kind of activity the assistants had to be able to work remotely, following Marconi's instructions. They were expected to be able to solve problems, make decisions with regard to adjustments and modifications also in the absence of direct instructions from their technical director. Moreover they were expected to describe accurately their work and to report to Marconi on the results they obtained in the course of the tests. Of utmost importance, therefore, was the capacity of the assistants to analyse and accurately report the results obtained from applying modifications to the system, both those requested by Marconi and those that they themselves deemed appropriate based on their own experience. Last but not least, the tasks that they were expected to perform were often to be carried out in challenging environmental settings, for example when the stations were located on lightships, and the workload was heavy; therefore the job was acceptable only to highly motivated people.

It should be kept in mind that the distance between the stations did not allow the participants in the experimental activities to keep in direct contact. The reports prepared by the assistants, which the company for obvious reasons wished to remain confidential, were sent by mail. It is precisely this extraordinarily rich mass of correspondence, kept in the Marconi Archives at the Bodleian Libraries in Oxford, that serves as the primary source for the analysis of the role they performed in their collaboration with Marconi.

3 From the Coherers to the Jiggers

In the case of the coherers Marconi had already availed himself of the observations and tests carried out by his assistants when, after the incorporation of the MWTC, he engaged in the attempt to improve the effectiveness and reliability of that first kind of detectors of wireless signals.[7] The 1896 patent gave a brief description of the coherers; however their production, in particular the components of the metallic filings positioned between the electrodes and their methods of preparation, remained known only to Marconi and his assistants.[8] John Cave and his brother Robert were hired to undertake that very task, due to their experience as instrument makers; however, the manual filing of fine metal grains for the coherers was often the first occupations assigned to the new recruits.[9]

The diaries and correspondence of Kemp, Cave and the other assistants, are a testimony to their contribution to the development of that first and notoriously troublesome type of detector, and also to the determination with which they carried out that task. The communications sent to Marconi report their observations on the results obtained using different types of metal filings and modifying the ways in which the coherers were

7 See the reproductions of these devices in Casonato, Spada, *infra*.

8 Guglielmo Marconi, "Improvements in transmitting electrical impulses and signals, and in apparatus therefor", UK patent no. 12,039, 1896.

9 Degna Marconi (1993, 53) gives a vivid description of how the manufacture of the coherers became a sort of 'rite of passage' for the new recruits. The young man who was assigned that task on his arrival in Poole in 1899 was Harry M. Dowsett, who was later to become the principal of the MWTC School of Wireless Telegraphy and performed administrative duties until his retirement. A similar experience is described by Charles Franklin in OBL MS Marconi 682, "Notes by Franklin", 6.

connected to other components of the receivers. They also endeavoured to put forward explanations for the different outcomes of their tests and to suggest alternative solutions. This experimental work on the coherers continued even when the Chelmsford factory was opened in 1898 and the industrial production of wireless equipment began, with John Cave being appointed foreman of the coherer department.[10]

The empirical research on tuning and the development of the jiggers is an equally valid example of the same collaborative effort, and the contribution offered by the assistants was just as important. In the early months of 1898 the first attempts had already begun to revise the system in such a way as to allow a certain degree of selectivity, while at the same time increasing the distance of transmission without raising the height of the antennas.[11]

In seeking a solution, Marconi began with what seemed like a clear opposition between two options. On the one hand there was his original arrangement – with the antennas of the transmitting and receiving devices connected to earth passing respectively through the circuits of the spark gap (the electromagnetic wave generator) and of the coherer. This gave good results in terms of transmission distance, but did not allow for tuning. On the other hand there was the solution adopted by Lodge in his patent on syntonic telegraphy which used a closed transmission system, that is to say not connected to earth. This solution yielded satisfying results but only for short-range transmission.

What Marconi chose was a sort of compromise. Very briefly, in the arrangement described in the first 1896 patent the receiving and transmitting antennas were respectively connected to the coherer and the radiator, and from these to earth. In the new provision, the induction coils that acted as frequency transformers (the jiggers), were inserted between the closed circuits of the receivers and transmitters, and the antennas connected to earth. Once again, it was a solution developed gradually and without a well-defined theory to guide the experimental process; in fact, at that stage the instruments capable of measuring the wave lengths produced by the transmitters were not yet available.[12] As already observed, and as was plainly admitted by Marconi himself, his attempts to improve the system advanced through trial and error.[13]

In the patent submitted to the London Patent Office in June 1898, the first in which the jiggers were described, there was no mention of the tuning between transmitting and receiving apparatus; the aim, as it was stated, was to reduce the interference caused by atmospheric disturbances, and at the same time to increase the signalling distances.[14] The new arrangement, which was at that stage adopted only for the receivers, involved inserting an induction coil into the receiving system in such a way as to connect inductively the circuits of the coherer and of the antenna: the primary winding of the coil was connected to the antenna, the secondary one to the coherer. Different types of coils were described in the patent, which varied in the dimension of the support on which the primary and

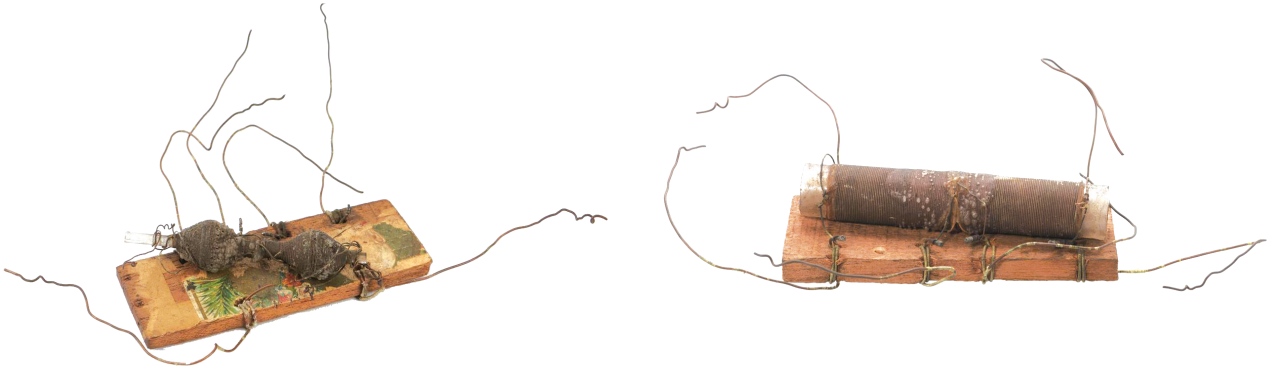
10 A substantial part of the correspondence between Marconi, Cave and other assistants is filed in OBL MS Marconi 178.

11 One of the first references to the research in progress appears in Kemp's diaries, in which the term jigger is used for the first time (26 October 1898). "Extracts from the diary of G.S. Kemp, 1897-1898", OBL MS Marconi 89.

12 Such an instrument was invented by Fleming in 1904. John Ambrose Fleming, "Improvements in instruments for the measurement of wave lengths in wireless telegraphy", UK patent no. 27,683, 1904.

13 For an in-depth analysis of the syntonic system developed by Marconi see Hong 2001, especially chapter 3.

14 Guglielmo Marconi and the Wireless Telegraph and Signal Co., "Improvements in apparatus employed in wireless telegraphy", UK patent no. 12,326, 1898.



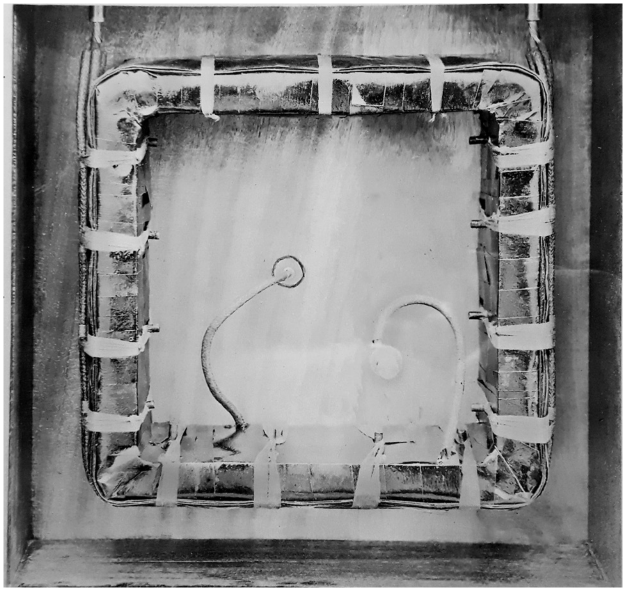
Figures 2a-b Two different examples of receiver jiggers with a one-layer spool and coils of secondary windings used by the Marconi Company and probably produced by the MWTC in Chelmsford, 1898, inv. 1923-434/4, inv. 1923-434/3, Science Museum Group, London. © The Board of Trustees of the Science Museum

secondary were wound, the number of layers, and the length of the wires. The jiggers were small glass tubes between 2 and 4 cm long and approximately 1 cm in diameter, around which was wound the primary circuit. This consisted of a silk-covered copper wire, which varied in diameter from 0.45 mm to 0.12 mm, and was generally wound in one or two layers. The secondary winding was wound above the first, from which it was separated by insulating material and consisted of a thinner silk-covered wire, which varied in diameter from 0.19 mm to 0.12 mm **[figs 2a-b]**.

Other models of receiver frequency transformers were tested in 1899, this time without specific reference to the nature of the improvements obtained with regard to the quality of communication. The two patents resulting from those tests described new forms of jiggers, with changes in the shape and the number of turns of the windings of the coils as well as the thickness and length of the wires. In the second patent in particular, a new fundamental detail was introduced: it was stated that the best tuning results were obtained when the length of the coil wires were in proportion to the length of the transmitting and receiving antennas.[15]

Research continued in the early months of 1900 and in April, again in the name of Marconi and his company, a new patent application was submitted to the Patent Office, the historical 7777. This time the objective was clearly stated in the first lines of text, namely, not only to increase the transmission distances, but also to “so control the action [of the apparatus] as to cause intelligible communications

15 Guglielmo Marconi and the Wireless Telegraph & Signal Co., “Improvements in apparatus employed in wireless telegraphy”, UK patent no. 6982, 1899; Guglielmo Marconi and the Wireless Telegraph & Signal Co., “Improvements in apparatus employed in wireless telegraphy”, UK patent no. 25,186, 1899.



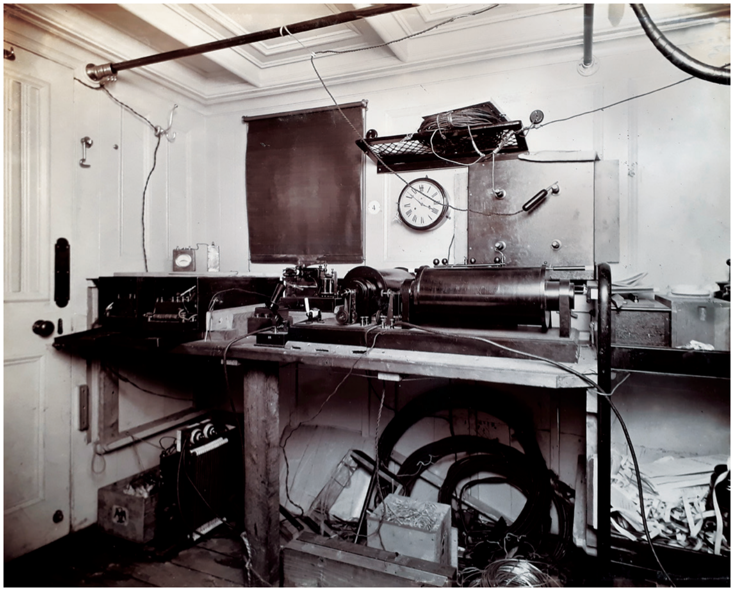


Figure 3a Jigger inside the box. OBL MS photograph b61

Figure 3b The radiotelegraphy cabin on board the ship *Philadelphia* in 1902. The box containing the jiggers hung on the wall. OBL MS photograph c253

to be established with one or more stations only out of a group of one or more receiving stations".[16] The objective was achieved by inserting frequency transformers into the transmitting circuits as well; the model of transmitting jigger described in the patent is shown **[fig. 3]**.

In reality, the attempts to improve the system continued at a relentless pace until the submission of the complete specification of the 7777 patent in February 1901 (see p. 82).[17] Just as in the past, in the preparation of that document Marconi trusted in the advice of the experts who had already assisted him with the first patent, the Carpmael patent agents and John Fletcher Moulton, and in Fleming's guidance (Guagnini 2002). At that point the road towards combining tuning with long-distance transmission was wide open, reinforcing the plan to cross the Atlantic by wireless which Marconi was already setting in motion.

16 Guglielmo Marconi and the Wireless Telegraph & Signal Company, "Improvements in apparatus for wireless telegraphy", UK patent no. 7777, 26 April 1900. In the patent text the use of the term 'syntonic tuning' as employed by Oliver Lodge is scrupulously avoided. The term used is resonance.

17 Marconi himself described the long series of laborious passages leading up to the so-called 'four-seven' patent in Marconi 1901.

4 The Role of the Assistants

As pointed out above, the laboratories where the experimental work was carried out were the installations set up by the MWTC for tests and demonstrations. From September 1898 the main station became the Hotel Haven in Poole, on the southern coast of England; other permanent shore stations were located at the Needles, on the Isle of Wight, and in 1899 at the Sandrock Hotel, Niton, on the southern coast of the Isle of Wight. In addition to those installations, several temporary stations, both on land and on shipboard, were specifically set up for the numerous demonstrations requested in that period by potential clients and public bodies. At the time the principal temporary stations were South Foreland (near Dover, on the English Channel) and the East Goodwin lightship (notoriously the most inhospitable of the locations due to the frequently appalling weather conditions) established at the eastern entrance to the English Channel for tests requested by Trinity House, the private company responsible for the monitoring of lighthouses along the British coastline; and Wimereux station, fitted for the demonstrations offered to representatives of the French government. Of particular importance, with regard to the experiments on the syntonic devices, were the stations set up in July 1899 on board the battleships *Alexandra*, *Europa* and *Juno*, during Royal Navy ship manoeuvres; and those installed in 1900 in Germany on board of the Borkum lightship and at the Borkum lighthouse, for communications with ships of the Norddeutscher Lloyd Steamship Company. Just as important again were the tests carried out in November 1899 on board of the transatlantic liner *St. Paul*, which was sailing from the United States to England.[18]

The tests and demonstrations carried out in those stations, all of them staffed with Marconi’s most trusted collaborators, offered extraordinary opportunities for advancements in the design of the system. Clearly Marconi issued detailed guidelines for the assistants’ work, but because they were operating far from the Poole and Chelmsford bases, they had to be capable of exercising a certain degree of autonomy in making decisions relative to the problems encountered while conducting the tests. Their responsibilities involved not only varying the configuration of the components of the system, including the antennas, but also rectifying them when the results were not satisfactory. With particular regard to tuning, it was their task to adjust the characteristics of the jiggers, for example varying the number of layers and the shape of the windings, as well as the thickness and length of the small tubes around which the wires of the primary and secondary wires were wound.[19] Adjustments were often required also for other components of the system that had to be balanced in such a way as to achieve the goal of resonance, among them condensers, resistances, relays and chocking coils.[20]

Given that most of this work was carried out remotely, and that the reports and evaluations on the results of the

18 In November 1899 Bradfield, Rickard, Bowden, and Denshaw accompanied Marconi on board the *St. Paul*. In the same year those assistants together with Bullocke and Dowsett participated in the Royal Navy tests alongside Marconi.

19 For example, in a letter to Marconi on 24 July 1900, Bradfield, who was in charge of setting up and operating the Borkum station, observed that “the experiments here transformed me into a first-class jigger winder. I must have tried quite 50 altogether” (Copy-letter books, OBL MS Marconi 182).

20 See correspondence in Copy-letter books, 1900-03, OBL MSS Marconi 182-3.

tests had to remain as usual strictly confidential, communication once again was confined to written correspondence.[21] Fortunately for us, one might say, because the result is an extraordinary repository of primary sources for an in-depth study of the transition from the early forms of frequency transformers to the production of the first syntonic apparatus. They allows us to examine how the assistants, as they became progressively more involved in the experiments on receiving and transmitting jiggers conveyed to Marconi not only accurate descriptions of how the tests were carried out, but also their own analysis of the results and recommendations on how the system could be improved. The correspondence reveals how, and to what extent, the assistants themselves played an active role in the identification of the solutions which were described in the complete specification of the 7777 patent filed in April 1901, and in the further developments of the research on tuning.[22] Among the assistants initially involved in the syntonic tests along with Kemp (whose diaries are a most detailed source of information also on this phase of Marconi's experimental work) were Bradfield, Bullocke, and Cave. From May 1898 Elliott, Paget, Rickard, Cahen, Murray, Bowden, and Lockyer joined the group.[23] As the programme of test and demonstrations intensified after 1901, new recruits joined the team of the assistants.[24]

The skills and vigorous commitment to work of these collaborators were of fundamental importance; thanks to their support Marconi and his company were able to convince potential clients that the tuned system, in which the jiggers were one of the main components, was the solution to selective communication. It should however be kept in mind that even when the tuned system was adopted in all the MWTC installations, the effective use of these devices required a considerable amount of skill and know-how on the part of the operators. As Fleming observed in 1900, drawing on his own direct experience,[25] and Sungook Hong correctly confirmed, tuning as it had been developed in that first pioneering phase was not a science but an art: “Coping with syntony required technical rather than mathematical skills. Marconi, with his jiggers, was the first to master it” (Hong 1990, 96): that is to say, obviously, Marconi and his collaborators.

21 Confidentiality was explicitly required in the employment contracts. The protection offered by patents could not guarantee that information about the construction procedures would remain inaccessible to potential competitors; it was equally important to prevent the circulation of news about the results of the experiments.

22 Copy-letter books, 1901-03, OBL MSS Marconi 182-3.

23 In November 1899 Bradfield, Rickard, Bowden and Denshaw accompanied Marconi on board the *St. Paul*. In the same year those assistants together with Bullocke and Dowsett participated in the Royal Navy tests alongside Marconi.

24 Two particularly rich documentary sources regarding the tests carried out by the assistants on syntonic tuning as well as on long-distance communication are OBL MS Marconi 188, which contains the correspondence between Marconi and Entwistle, manager of the Poldhu station from 1901 to 1905; and OBL MS Marconi 197, which contains the correspondence and reports of other assistants, most notably the experiments carried in 1902 by St. Vincent Pletts on transmitting jiggers at the Frinton Station near the headquarters of the MWTC; and Woodward's worked at the Broomfield Rd Station, London, in 1904.

25 “Although easy to describe, it requires great dexterity and skill to effect the required tuning [with Marconi's jigger]” (Fleming 1900, 49).

5 From Experimentation to Production – and Beyond

Based on this prolonged and intense experimentation, the production of frequency transformers began at the Chelmsford factory from 1901. Three types of jiggers, marked with a code and intended for receiver apparatus, were initially produced for sale: model 112, model 132 and model 268, to which corresponded antenna of differing lengths. These were the models used by the 32 devices supplied to the Royal Navy in 1900 **[fig. 3b]**.[26] But it was a first step: even after the first tuned apparatus began to leave the factory, research on frequency transformers continued with undiminished intensity. The aim was not only to improve simultaneous transmission and selective tuning, but also to design the kind of jiggers required for the high-power transmitting stations that were being planned for increasingly long-range transmission – most notably for transatlantic communication. When a new form of frequency transformer designed by Fleming did not prove successful, Marconi went back to developing his own model of jigger.[27] He did so again in collaboration with his well-established group of trusted and experienced assistants – in particular Richard Vyvyan and William Entwistle. The former was a graduate of Faraday House, one of the most prestigious (and costly) London schools for training of electrical engineers, who joined the MWTC after a working experience at Ferranti Ltd. Entwistle had attended electrical engineering courses at the Chelsea Polytechnic in London. Both of them were among Marconi’s closest collaborators in the construction and management of the transatlantic stations of Poldhu and Glace Bay.[28] As for the further development of tuned devices, it was Charles Franklin in 1907 who, on behalf of the MWTC, designed and patented what would become the standard equipment for frequency selection in wireless telegraphy, namely the multiple tuners.[29]

6 Conclusion

The role of the group of assistants who joined the MWTC in the first decade of its activity did not remain limited to strictly technical tasks. From 1910 onwards, after their involvement in experimental work and in the creation of a rapidly expanding network of company installations, many of the assistants took on administrative and managerial positions within the company, and retained them until the very end of their working life. Kemp and Paget in particular were often called to Marconi’s side at public events to celebrate his pioneering role in the development of wireless telegraphy. Gray, who had already been made chief of staff in 1904, was subsequently appointed MWTC head engineer and remained in that capacity until his retirement in 1931. Many other assistants were assigned to administrative positions: for example, Bradfield, the technical manager of the American subsidiary, was

26 Henry W. Allen, MWTC secretary, to Marconi, 1 November 1900, OBS MS Marconi 245.

27 For an analysis of the abandonment of Fleming’s frequency transformer and the return to Marconi’s model see Hong 2001, 76-9.

28 Both Vyvyan and Entwistle are among the assistants that Marconi mentions and thanks in “The Progress of Electric Space Telegraphy” 1902, 208.

29 Charles S. Franklin and MWTCo, “Improvements in receiving apparatus for wireless telegraphy”, UK patent no. 12960. Franklin was the author of 65 patents, most of them held jointly with the Company. Other assistants were authors of patents applied for on behalf of the MWTCo; among them Round, Gray, Entwistle and Dowsett.

promoted to the Board of directors of both the MWTC and the Marconi International Marine Company; Vyvyan was the chief engineer for the construction of the most important MWTC radiotelegraphy stations abroad; and Dowsett was entrusted with the position of research director.

As the initial group of collaborators gradually distanced itself from direct involvement in experimental activity, other new recruits joined in. Marconi, in fact, continued to select among them his own personal staff; among those who maintained a high profile as researchers well into the interwar period were two of the assistants mentioned in the first part of this essay: Round (Baker, Hance 2010) and Franklin (Symons 2004).

However, it is important to bear in mind that in the period leading up to 1914, there was no research unit officially set up within the MWTC; that responsibility remained totally under Marconi's direct control. The consultancy contract offered to Fleming, which lasted from 1899 to 1914, was definitely a substantial investment for a company technologically very ambitious but still in its early phase of development; and yet, although he carried out his job with much energy and determination, he found it hard to fully integrate into Marconi's project. As for the assistants, they remained strongly tied to the man they saw as their leader – to Marconi rather than to the MWTC itself. As a result, the nature and worth of their contribution becomes apparent only through the direct relation they established with their technical director. It remains to be ascertained – and it is an aspect that deserves to be considered from a historical perspective – to what extent this strong vertically structured personal relation constituted a limiting factor in the development of a more effective research organisation within the MWTC, especially when by the 1910s the competition of rival companies began to challenge its technological leadership in the field of wireless communications.

Table 1 Qualification and chronological order of the hiring of assistants

1897	
Bradfield, W.W.	Finsbury Technical College, London
Glanville, E.	BSc King's College, Dublin
Bullocke, G.L.	King's College, London
Cave, J.	Scientific instrument maker
Kemp, G.S.	Royal Navy and General Post Office
1898	
Elliott, W.R.	
Paget, P.W.	Finsbury Technical College, London
Rickard, C.E.	University College, London
Cahen, A.A.	BSc Central Institution, London
Erskine Murray, J.	BSc Glasgow University, research at the Cavendish Laboratory, Cambridge
Bowden, T.	Finsbury Technical College, London
Lockyer, C.J.	
1899	
Cave, R.F.	Scientific instrument maker
Densham, W.	General Post Office
Gray, A.	BSc Glasgow University, West India and Panama Telegraph Company
Dowsett, H.M.	Finsbury Technical College, London; British Thompson Houston Company, Ferranti Company
Stacey, F.S.	Finsbury Technical College, London
Franklin, C.S.	Finsbury Technical College, London
Pletts, J. St Vincent	Central Institution, London
Newman, F.	Eastern Cable Company
Stacey, F.S.	Finsbury Technical College, London
Woodward, P.J.	Finsbury Technical College, London
1900	
Hepworth, W.C.P.	South London School of Telegraphy
Hobbs, T.E.	General Post Office
Vyvyan, R.N.	Faraday House, London; Ferranti Company
1901	
Ashley, L.N.	Crompton Dynamo Company
Entwistle, W.S.	
Ginman, A.H.	
Tyler, E.G.	Battersea & Chelsea Polytechnic, Kincaid Waller & Manville (consulting electrical engineers)
1902	
Bangay, R.D.	Finsbury Technical College, London
Burrows, F.E.	Central Institution, London
Round, H.J.	Royal College of Science, London

* The selection of the names is based on the information provided by the MWTC recruitment lists cross-referenced with mentions in the documentary sources of the Marconi Archive, in particular the correspondence in OBL MSS Marconi 182-3; 188. Information on training and work experience is not available for all the assistants.

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