From Poldhu to the Italian Station of Coltano: Marconi and the First Years of Transcontinental Wireless

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Abstract

This paper presents the evolution of low-frequency, high-power transcontinental transmission, starting from the first successful transatlantic link from Poldhu up to the Italian transcontinental station of Coltano. The trend toward higher and higher transmitting power, and the dead end into which wireless was heading if it were not for research in the higher frequency ranges, are pointed out.

Keywords: History; Marconi; VLF radio communication; VLF radio propagation; HF radio communication; HF radio propagation; microwave radio communication;

1. Introduction

This paper contains a short history of the achievements of Marconi immediately following his first transcontinental wireless link, between Cornwall and Newfoundland. The first section shortly summarizes that first achievement. The following two sections describe Marconi's work in the year 1902, mainly on ships. The fifth section is devoted to the building of the transmitting stations in America and the setting-up of a two-way transatlantic link. Finally, the sixth section is devoted to the last, gigantic, transcontinental VLF stations, and the seventh section considers the rise of shortwave transmissions.

2. Poldhu: The First Message and Afterwards

The first successful transcontinental radio link was officially obtained on December 12, 1901, between the Poldhu ultra-powerful radio station and a receiving station in Newfoundland. This has been deeply and widely described in many papers and special sessions that flourished in 2001, on the occasion of the centennial of that event. Some controversy regarding the fact that Marconi did indeed attain such a success was also raised [1]. This paper does not focus much on that event, but rather investigates the developments that followed it.

What is interesting to note is the brute-force approach used in such an achievement. To those who were telling him that radio waves propagate in a straight line and, hence, that he would never manage to get a transatlantic link, Marconi answered,

> *Non vedo perchè dovrebbe essere altrimenti; basta che l'apparecchio trasmittente abbia l'energia sufficiente per lanciare le onde al di là dell'oceano.* [2]
>
> [I cannot see any reason why not; it is sufficient that the energy of the transmitter is enough to launch the waves across the ocean.]

Powers of about 15 kW were used for signals, with a wavelength that is believed to have been something less than 2 km, and a nearly omnidirectional antenna. The first outcome of this success was the threat of a suit for damages from the Anglo-American Telegraph Cable Company. Marconi commented:

> *Mi si imponeva di sospendere i miei esperimenti, di ritirare i miei apparecchi, pena, in caso contrario, il ricorso alle vie giudiziarie. Ed io sospesi gli esperimenti, ma ormai avevo vinto. Le onde elettriche avevano varcato vittoriosamente l'atlantico.* [2]
>
> [I was forced to suspend my experiments, to retire my pieces of apparatus, or, otherwise, legal steps would have been taken. I suspended the experiments, but I had already won. Electromagnetic waves had overcome successfully the Atlantic Ocean.]

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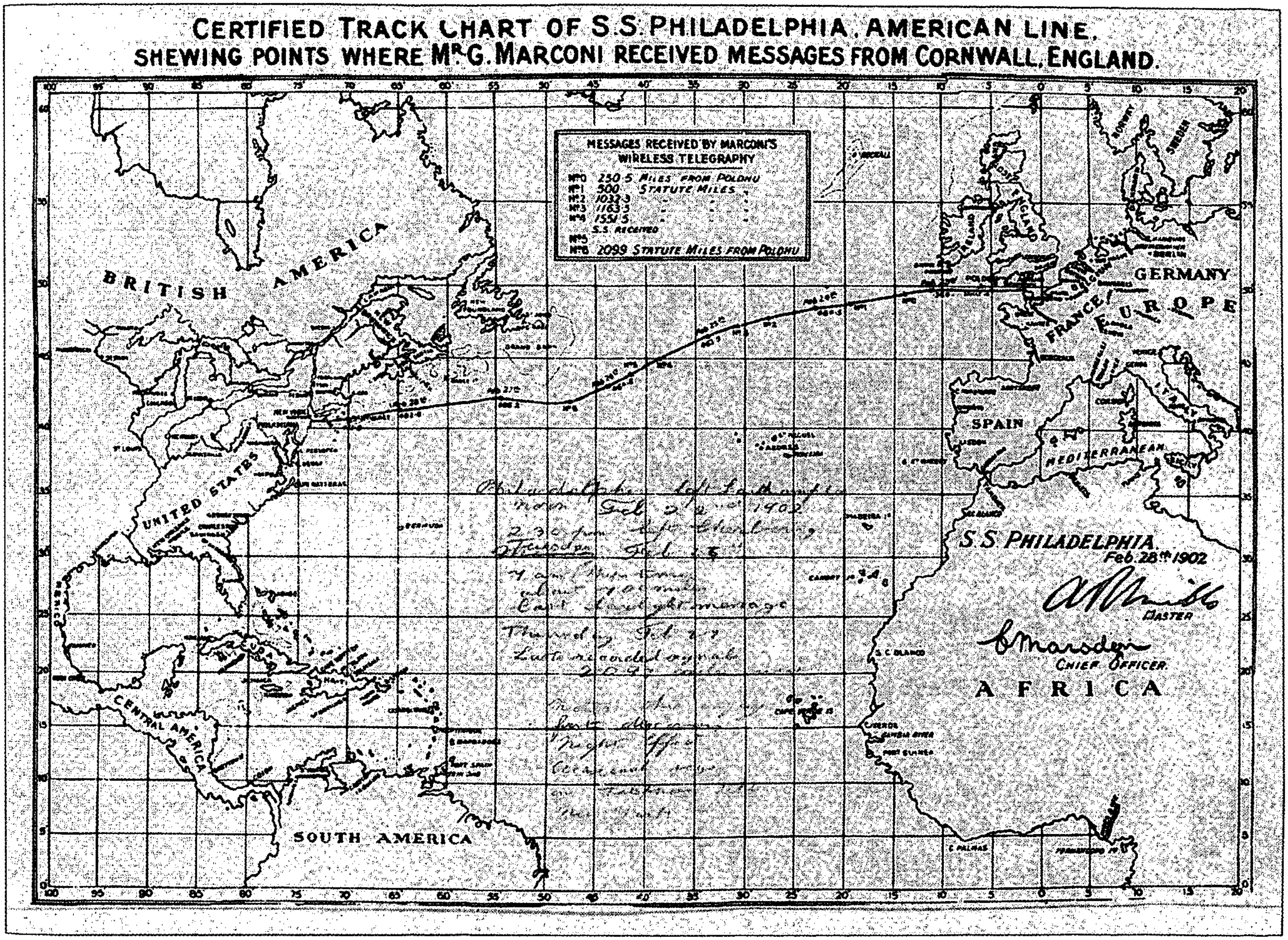

Figure 1. A certified track chart of the transatlantic liner *Philadelphia*, with annotations on successful receptions (from [4], p. 73).

Those legal problems were a minor nuisance. Marconi was not yet ready to commercially exploit a transatlantic link. Some points were still to be clarified, and Marconi himself pointed out three major issues:

> *Superata la curvatura della terra, rimangono tre importanti ostacoli opposti dalla natura allo sviluppò della radiotelegrafia: la luce solare, il cui effettò debbo ancora definire; le scariche elettriche atmosferiche, e le grandi estensioni di terreno montagnoso. Per quanto riguarda la luce solare, eseguirò fra pochi giorni delle importanti esperienze pratiche a bordo del transatlantico* Philadelphia *che mi riporterà in America.* [3]

> [After having overcome Earth curvature, three big obstacles remain for radiotelegraphy development: sunlight, whose effect I must still define; atmospheric electrical discharges; and large extension of mountains. For what concerns sunlight, I will carry out, in a few days, some important experiments aboard the liner *Philadelphia*, which will take me back to America.]

3. Aboard *Philadelphia*: The Day and the Night

1902 was the year of Marconi's great sailing experiments. Ships began to be equipped with radio systems, and Marconi investigated the propagation phenomena deeply. On February 22, the liner *Philadelphia* set sail from Cherbourg to New York, where it arrived on March 1. Marconi was aboard, with a receiving apparatus, and a single-wire aerial placed from the top of the mast, 60 m above sea level, to the main deck.

> *Prima che lasciassi l'Inghilterra gli operatori di Poldhu avevano ricevuto istruzione di lanciare dei segnali ad intervalli determinati durante tutta la settimana necessaria a compiere il viaggio.* [2]

> [Before leaving England, I instructed the operators in Poldhu to transmit signals at specific intervals throughout the whole week of the voyage.]

During the one-week voyage to America (Figure 1), Marconi observed that Poldhu signals could be received 1126 km away during daytime, but as far away as 2496 km at night. These observations led to important considerations of the effect of the sun on radio communications.

> *Fu durante le prove sul Philadelphia che mi accorsi di un effetto deciso e dannoso della luce del giorno sulla trasmissione per telegrafia senza fili....sono incline a ritenere che l'assorbimento delle onde elettromagnetiche durante il giorno sia dovuto alla ionizzazione delle molecole gassose dell'aria, prodotta dalla luce ultravioletta....* [2]

> [It was during the experiments on the Philadelphia that I noticed a sharp harmful effect of sunlight on wireless telegraphy....I think that the absorption of electromagnetic waves in daytime is due to the ionization of the gaseous molecules of the air produced by ultraviolet light.]

The scientific explanation of the phenomenon was still to be better developed, but the fact that nighttime transmission could reach further distances was established. The key point of clearer and stronger propagation of a radio signal at nighttime, rather than at daytime, was anyway assessed, and this would be of great help in further development.

4. The *Carlo Alberto*: Wireless Across Land

When Marconi went back to Europe, he patented a new kind of receiver, the magnetic detector. This proved to be more sensitive than his previous coherers, and was to be used in most of his subsequent experiments. This was based on earlier Rutherford observations of the demagnetization of magnetized iron in a radio-frequency electromagnetic field. It was made of a loop of very thin iron wire, passing through two separate, collinear, copper coils and two permanent magnets. One of the copper coils was connected to the antenna terminals; the other was connected to a speaker. By having the wire run through the magnets, the wire itself was magnetized, and by passing through the coils in the presence of a signal, the wire was demagnetized. This caused a magnetic-flux variation – effectively demodulating the signal – that was signaled by the speakers.

After the good outcomes obtained in 1901 and in early 1902, the Italian government decided to put a ship at Marconi's disposal to continue his experiments. This was also the occasion of a representative mission to St. Petersburg, for celebrations in honor of Czar Nicholas II. The Italian battleship *Carlo Alberto* was committed to the mission. On its way from Italy to Russia, the ship stopped in the British harbor of Poole from June 19 to July 7, to let Marconi board and to build a convenient aerial.

With the ship at his complete disposal, Marconi managed to build a much better aerial than the one onboard the *Philadelphia*, raising both masts of about 10 m and building a complete fan of 50 wires (Figure 2). From July to September, Marconi sailed on a

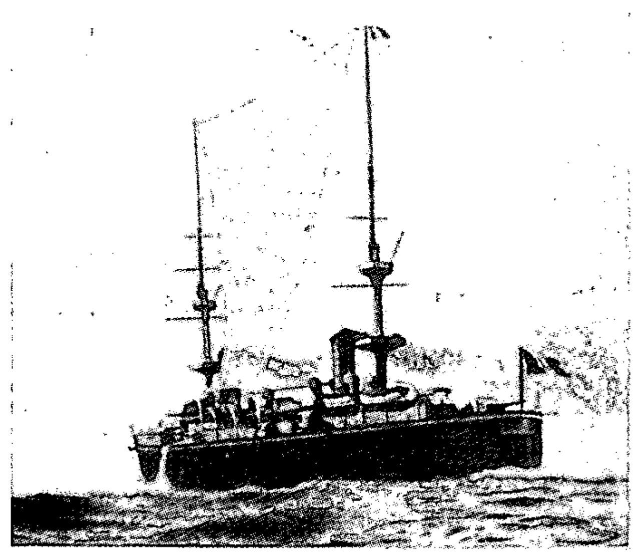

Figure 2. An artist's painting of the *HMS Carlo Alberto* with the large aerial between the masts (Figure 13 in [3]).

long voyage from Poole, England, to Kronstrad, Russia, and back to La Spezia, Italy (Figure 3). Marconi experimented with his new magnetic detector, still using Poldhu as the transmitter. On the way to Russia, the experiments were interesting but not very significant, since the link was mainly above the sea, and Denmark and south Sweden are rather flat. On the return, shortly after Gibraltar, with all of Spain between the transmitter in Poldhu and the ship as close as possible to the Spanish coast, Marconi first managed to receive a message across a really large body of land. Some days later, in Cagliari, with the whole of Sardinia and France in between, he managed to receive a second message (Figure 4). The results were so interesting that King Vittorio Emanuele III granted the use of the ship to Marconi for a second campaign of experiments in the Atlantic. These experiments basically validated the experiments carried out on the *Philadelphia*, but with a better aerial and receiver. There is a general lack of details in Marconi's publications. Anyway, it is known that the frequency used in these experiments – at least when the *Carlo Alberto* was in Sidney harbor, NS, in October 1902, was 272 kHz.

5. Glace Bay and Cape Cod: West-to-East Transatlantic Wireless

In America, Marconi reached Glace Bay, on the Table Head headland in Nova Scotia, on October 31. The four towers that were to hold the aerial were almost completed. In the meantime, new wooden towers, much alike those in Glace Bay, were being constructed in Poldhu.

On December 20, Marconi officially opened transmission from Canada to England, from Glace Bay to Poldhu, with telegrams to the King of England and to the King of Italy. The first bidirectional radio link between Europe and America was established.

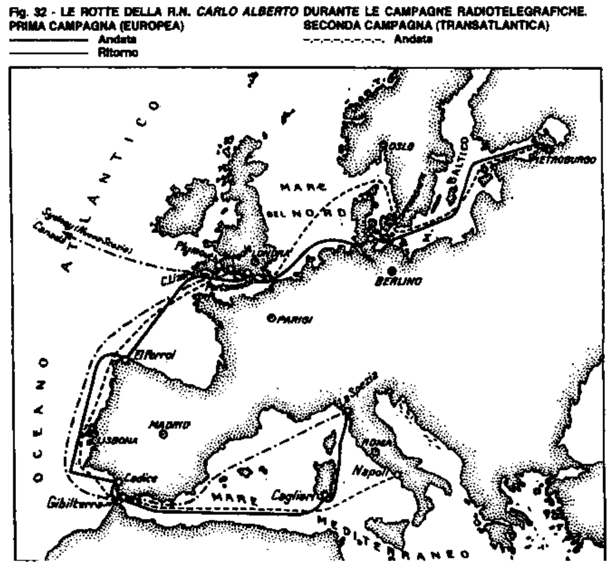

Figure 3. A track chart of *HMS Carlo Alberto* during its European voyage, and of the first part of its transatlantic voyage (Figure 32 in [2]).

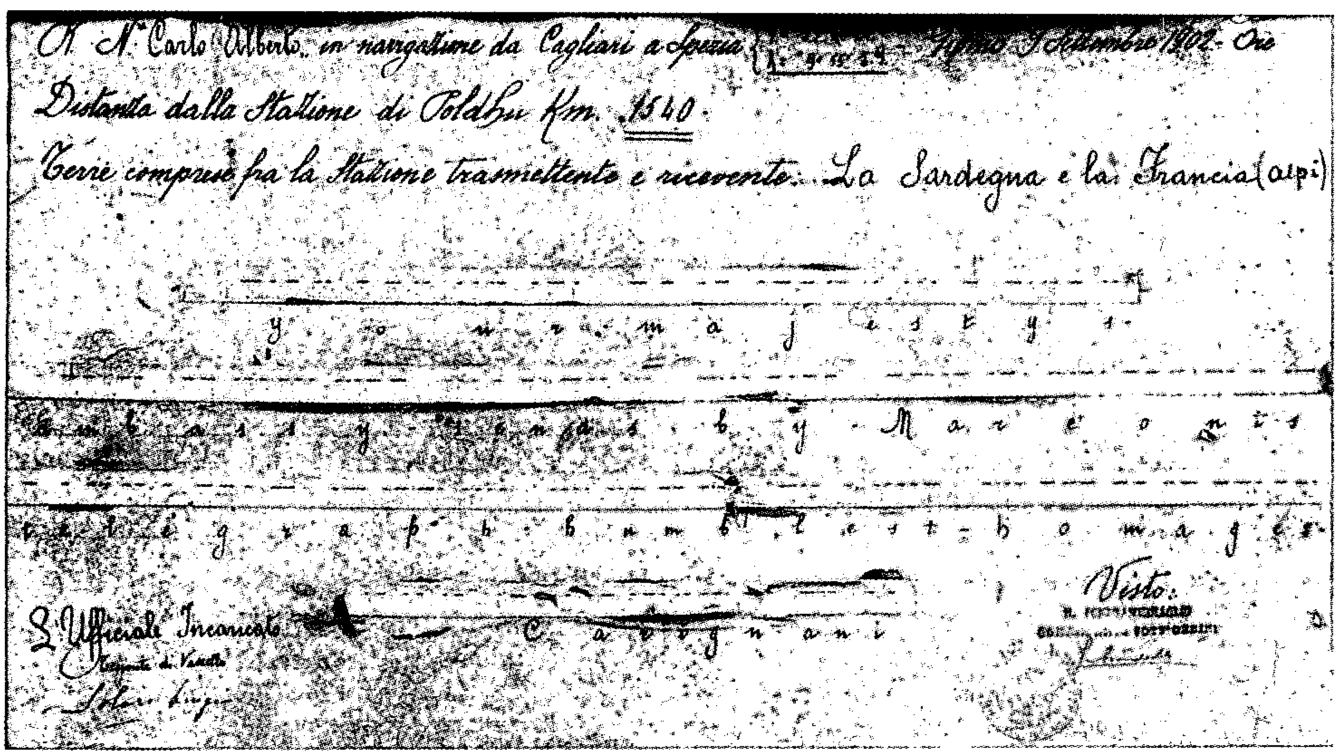
R. N. Carlo Alberto in navigazione da Cagliari a Spezia
Distanza dalla Stazione di Poldhu Km. 1540
Terre comprese fra la Stazione trasmittente e ricevente La Sardegna e la Francia (alpi)

Figure 4. A message transmitted from Poldhu and received in Cagliari by Marconi on the *Carlo Alberto* (Figure 14 in [3]).

On January 19, 1903, the second American station was completed at Cape Cod, Massachusetts. The first message from there to Poldhu was sent from President Roosevelt to King Edward VII[1].

Marconi himself noted in his memoirs that this second link was much more important politically and industrially, but that it was also much opposed by the cable companies and newspapers. In this latter station, the transmitting power was 25 kW, and the aerial comprised twenty wires held by four 64 m towers.

6. Clifden and Coltano: Signals Across the World

In 1903, the Italian Ministry of Mail and Telegraph asked Marconi to build a transcontinental station linking Italy to Argentina, to where millions of Italians had emigrated. For this station, Marconi chose the location of Coltano, near Pisa, in the King's estate of San Rossore, since the place was flat and roughly at the same distance from Rome (Italy's capital) and from Milan (the major industrial city).

The construction of this station – which was to be much more powerful than all the previous stations, the two nations being much farther away than England and Canada or the United States – experienced many difficulties. Indeed, the first nucleus was completed only in 1910, and it wasn't Marconi's custom to spend seven years on a single project.

Thus, in the meantime, Marconi set up the Clifden ultra-powerful station (1906). It worked at 200 kHz ($\lambda = 1500\,\text{m}$), with a transmitting power of 300 kW. In 1907, this station and the station in Glace Bay inaugurated the first commercial transatlantic link. Clifden station was able to send around 14,000 words per day, at 10¢ per word (5¢ for the press), at a frequency of 45 kHz.

It is worth noting that Marconi was already aware of the low efficiency of omnidirectional inverted-pyramid antennas (like those in Poldhu and Glace bay) for point-to-point radio links. Indeed, during his experiments on Carlo Alberto and in Cape Cod, he started work on horizontal, somewhat-directive, aerials:

> *Occorre aumentare l'efficienza e l'indipendenza delle stazioni destinate a collegare punti fissi a grandi distanze. L'attuale sistema di radiazione circolare sarà sempre utilissimo per le navi e per altre applicazioni radio; ma per servizi fissi intercontinentali occorre concentrare la radiazione dell'energia entro un ristretto settore.* [3]
>
> [It is necessary to raise the efficiency and the independency of fixed stations at large distances. The current circular radiation system will always be good for ships and other radio applications; but for transcontinental fixed links it is necessary to concentrate the radiation in a narrow sector.]

This new kind of aerial was also to be used both in Clifden and Coltano (Figure 7, foreground).

In 1910, Marconi sailed to Buenos Aires on the ship *Principessa Mafalda*, maintaining a radio link with Coltano (still to be fully completed), Clifden, and Glace Bay up to Buenos Aires, Argentina, where a receiving station was nearly finished.

The Coltano site, albeit started in 1904, was officially inaugurated on December 13, 1910, with a transmission towards the Italian colonies in Massawa (Eritrea), Mogadishu (Somalia), and the station in Glace Bay (Canada), at 43 kHz. On that occasion Marconi stressed the fact that Mogadishu was 2000 km away, less

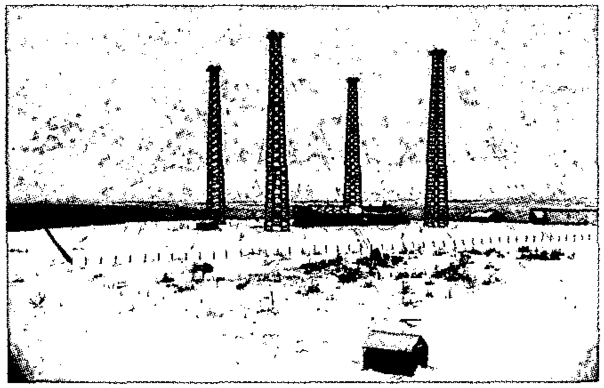

Figure 5. The station at Glace Bay (from [4], p. 80).

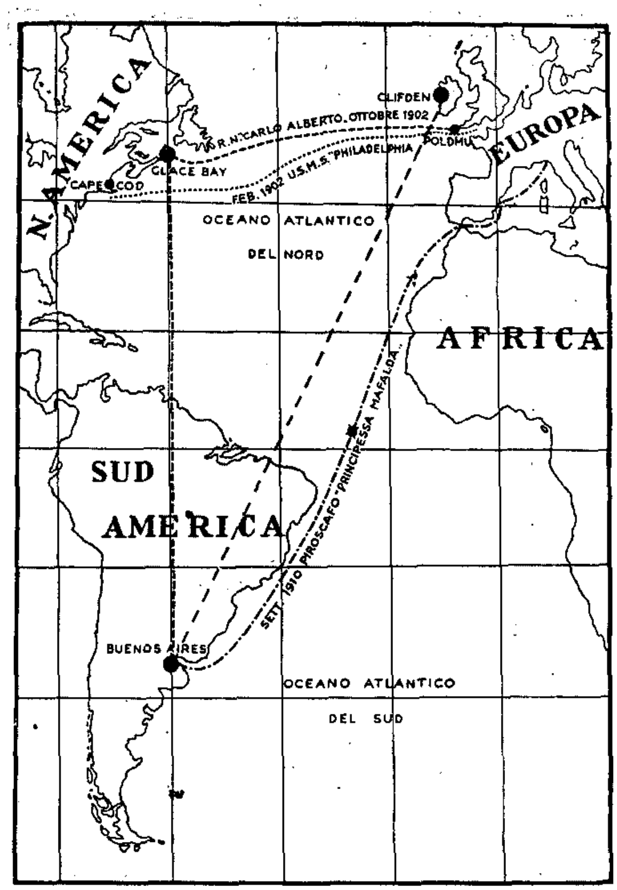

Figure 6. A track chart of the transatlantic liner *Principessa Mafalda* (Figure 11 in [5]).

[1]Fessenden [6] and some authors after him were fairly skeptical of Marconi's achievements, and affirmed that this message was actually sent by cable first, and by wireless only later on.

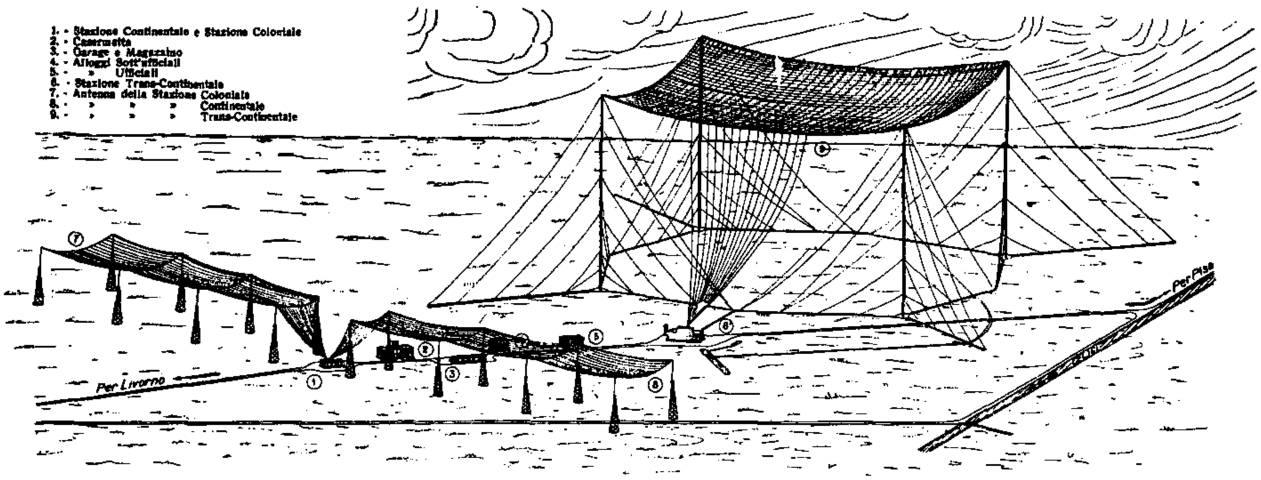

Figure 7. The layout of the Coltano station: The original Marconi station with two directive horizontal aerials is in the foreground. In the background is the later, ultra-powerful station with an omnidirectional aerial (Figure 2 in [7]).

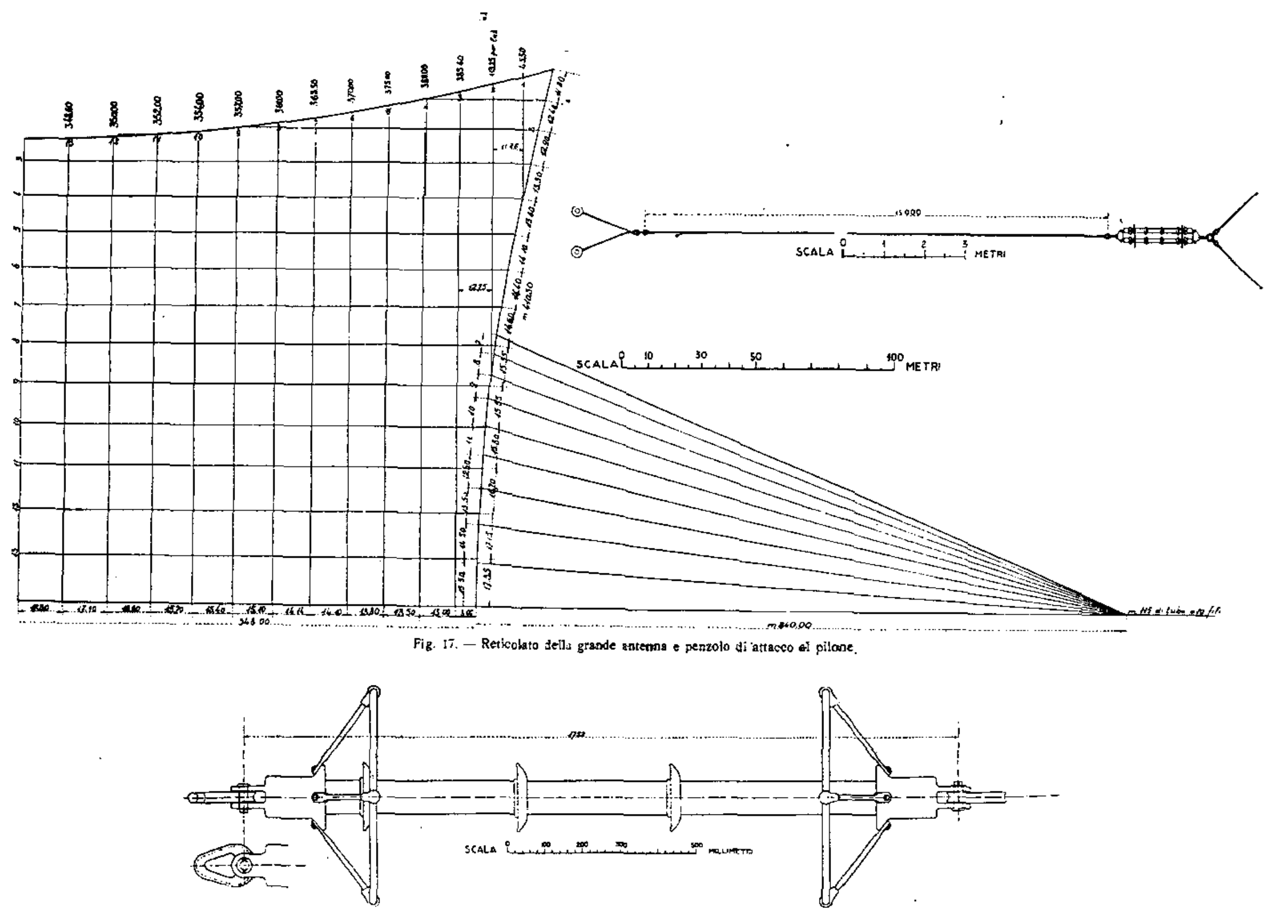

Figure 8. The layout of the Coltano transcontinental aerial pavilion, with a comprehensive diagram of the feeding fan and a sketch of an insulator (Figure 18 in [7]).

than other communications already achieved, but that the link was happening over the Sahara desert, not over the sea, and this proved again that all those who affirmed that long-range propagation was possible only over the ocean were wrong.

From 1919 to 1924, the Coltano site was enhanced with a new station and aerial, thanks also to the work of another pioneer of Italian radio communications: Giancarlo Vallauri. A bigger transcontinental aerial was added to the original Marconi station and aerials by the Italian Navy (Figure 7, background). The final stage of the transmitter driving the bigger antenna was capable of producing 200 kW and, with later refinement, 250 kW. The four pillars sustaining the antenna were 250 m high. As a comparison, the Cape Cod aerial was 64 m high, while the pillars of the Clifden aerial were 80 m high [7].

The pavilion itself was 420 m × 420 m wide, made of a net of phosphorous-bronze wires 3.4 mm thick and spaced about 15 m apart, one from the other. The net was reinforced with steel cables for the outer wires, for a total weight of about four tons (Figure 8). In the thirties, the station was able to communicate with the Italian ship *Conte Rosso*, sailing in the Chinese sea, 10,000 miles away, and with the whole of Asia in between .

7. The Twilight of VLF and the Dawn of Microwaves

The Coltano station was the biggest in the world at the epoch; nevertheless, big, non-directive long-wave stations were coming to an end. During World War I and in the following years, Marconi himself switched toward short waves (1 MHz, $\lambda = 300$ m) first, and then, step-by-step, to microwaves (more than 300 MHz, $\lambda < 1$ m), as described in a recent paper in this *Magazine* [8].

Directive reflector antennas were possible, and comparably higher distances were reachable with lower-power transmitters. Marconi started experimenting with parabolic cylinders with a single-wire aerial in the focal line (Figure 9). As an outcome of such experiments, Marconi managed to build up a shortwave system for the British empire, connecting, in the twenties, all English colonies, protectorates, and Commonwealth members all over the world (Figure 10) [9].

In 1923, Marconi wrote about this link that the transmitter power was 12 kW, of which 9 kW was effectively radiated by the antenna, and that he carried out experiments between Poldhu and

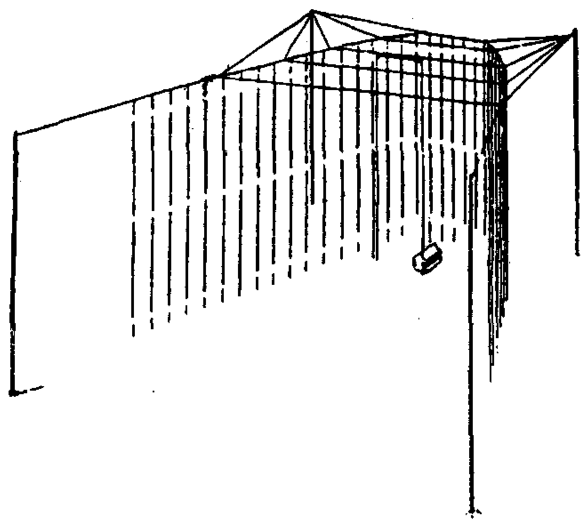

Figure 9. The layout of a parabolic-cylinder reflector antenna by Marconi (Figure 1 in [9]).

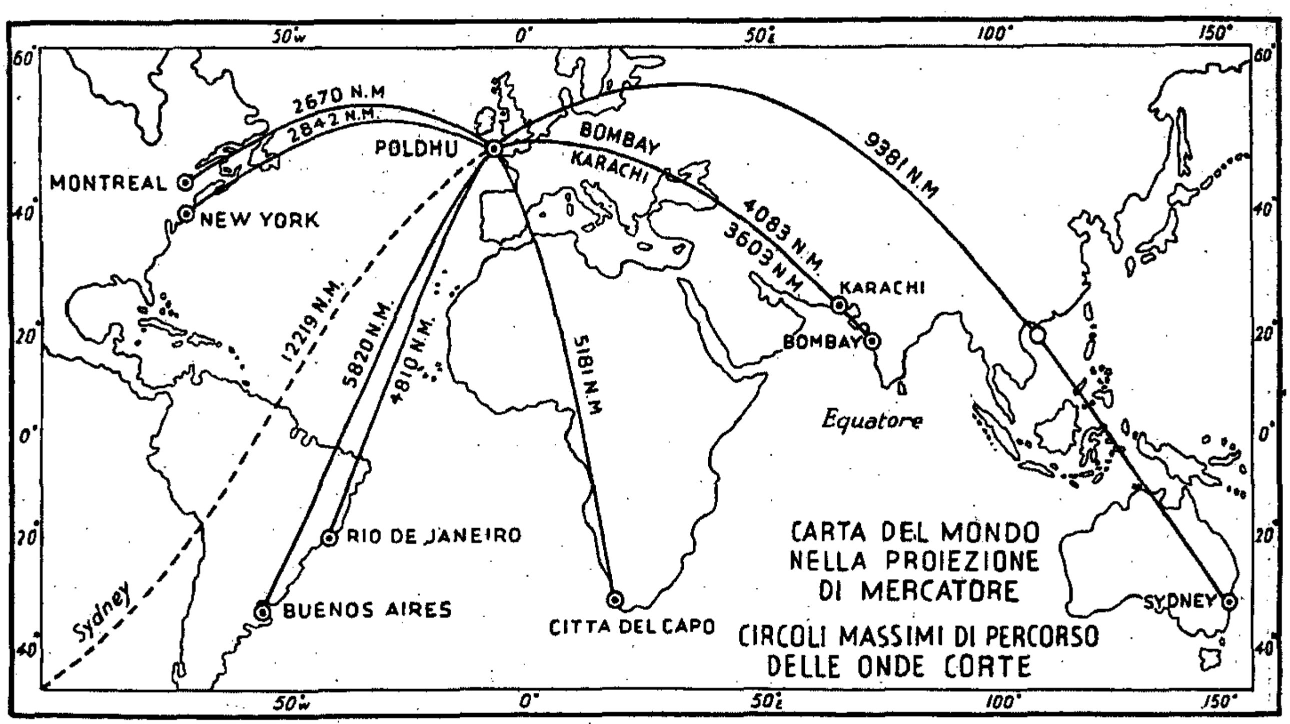

Figure 10. The British shortwave network (Figure 3 in [9]).

his ship, *Elettra*. His judgment was that a single kW of transmitting power could grant commercial links for the whole 24 hours (not just by night) up to a distance of 4200 km. In the following year, 1924, Marconi built four stations besides the one in Poldhu – Canada, India, South Africa, and Australia – each featuring a power of 20 kW. Links were only between England and the other station, with wavelengths from 16 m to 34 m. Marconi reported that the system could provide 500 words per minute in the month of May of that year.

8. Conclusions

The first twenty years of the last century saw the rapid emergence of the new telecommunications medium: the radio. The tireless Marconi brought long-wave communications from a proof-of-concept to a fully economically exploitable reality in more or less one decade, thanks to his many experiments, some of which were described in this paper.

Long waves were eventually doomed to give way to short waves, which could be used with lower-power transmitters, smaller and directive aerials, and new kinds of receivers. This was again to be started by Marconi, as the last section described.

9. Acknowledgement

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Introducing the Feature Article Authors

Giuseppe Pelosi was born in Pisa, Italy. He received the Laurea (Doctor) degree in Physics (summa cum laude) from the University of Florence in 1976. Since 1979, he has been with the Department of Electronics and Telecommunications of the same University, where he is currently a Professor. He was a Visiting Scientist at McGill University, Montreal, Canada, in 1994 and 1995.

Prof. Pelosi has been mainly involved in research in the fields of numerical and asymptotic techniques for applied electromagnetics. He is coauthor of *Finite Elements for Wave Electromagnetics* (IEEE Press, 1994), *Finite Element Software for Microwave Engineering* (Wiley, 1996), and *Quick Finite Elements for Electromagnetic Fields* (Artech House, 1998). His past research involved extensions and applications of the Geometrical Theory of Diffraction, as well as methods for radar cross section analysis of complex targets. His current research activities are mainly devoted to the development of numerical procedures in the context of the Finite Element Method, with particular emphasis on microwave and millimeter-wave engineering (antennas, circuits, devices, and scattering problems). He is a member of the Board of Directors of the Applied Computational Electromagnetics Society.

Stefano Selleri was born in Viareggio, Italy, on December 9, 1968. He obtained his degree (Laurea), cum laude, in Electronic Engineering, and his PhD in Computer Science and Telecommunications from the University of Florence in 1992 and 1997, respectively. In 1992, he was a Visiting Scholar at the University of Michigan, Ann Arbor, Michigan; in 1994, at McGill University, Montreal, Canada; in 1997, at the Laboratoire d'Electronique of the University of Nice – Sophia Antipolis, France. From February to July, 1998, he was a researcher at the Centre National d'Etudes Telecommunications (CNET) France Telecom – La Turbie, France. He is currently an Assistant Professor at the University of Florence, where he conducts research on numerical modeling of microwave devices and circuits.