BY HENRY M. BRADFORD

DID MARCONI RECEIVE TRANSATLANTIC RADIO SIGNALS IN 1901?

We are again fortunate to have another article from Henry Bradford on the early years of the Marconi transatlantic stations. Henry presents a thought-provoking discourse on the controversy associated with Marconi's earliest transatlantic experiments. There's no doubt in my mind that, due to Marconi's misunderstanding of the limitations of his receiving equipment, the letter "S" was really heard on HF, not on MF as the inventor claimed.

Give this article a whirl and see if you are convinced. If you are convinced, you might speculate, as I did, where communications technology would be today if the communications effectiveness of HF was uncovered at the turn of the 20 th century, instead of some 25 years later.— Frank J. Lotito, Editor, "Below 535"

In December 1901, Marconi claimed to have received, at St. John's, Newfoundland, a radio test signal transmitted by his high-powered spark transmitter station at Poldhu, Cornwall, England. This was the first reported transatlantic radio transmission, and it convinced Marconi that a transatlantic radio service was possible. In spite of his subsequent successes in transatlantic wireless communications, his celebrated original claim has remained the subject of controversy.

The doubts today centre around the reported wavelength and time of day: 366 metres (820 kHz), around midday and early afternoon at St. John's. At this time, much or all of the transatlantic path was in daylight. In the light of modern knowledge about radio propagation, Marconi could hardly have picked a worse combination of frequency and time of day for the transatlantic experiment. Imagine attempting transatlantic transmission on the North American AM broadcast band in the middle of the day!

As most radio listeners know, reception at these frequencies typically is restricted to within a few hundred miles from the station in the daytime, though it may extend many times further at night. The reason for this is this is that the D-layer of the ionosphere absorbs the energy of radio waves in this frequency range during the day, but disappears at night, allowing long distance reception via reflections from higher levels in the ionosphere.

So how did Marconi receive transatlantic radio signals in the middle of the day in what now is the AM broadcast band —if indeed he did? Let us examine all his early efforts at long distance radio communications for an explanation. (See References [1] through [3] for full descriptions of the events and equipment.) In 1900, Marconi built a powerful new shore station at Poldhu, Cornwall for ship-shore radio communications and experimentation. It was designed by Professor J. A.

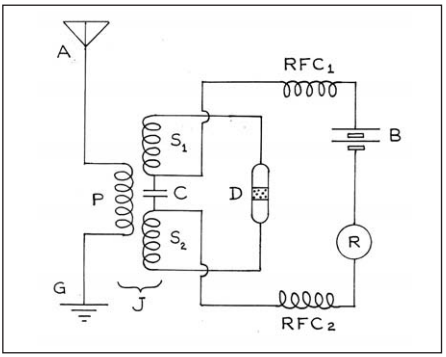

Fig. 1. Schematic of untuned receiver. A = antenna; G = ground; J = r.f. antenna transformer (called a "jigger"); P = primary coil; S1, S2 = halves of split secondary coil; D = coherer detector; C = r.f. bypass capacitor; RFC1, RFC2 = r.f. chokes; B = Battery; R = relay. When triggered by an r.f. signal voltage from J, the resistance of the coherer dropped, increasing the current in the d.c. circuit consisting of D, S1, S2, RFC1, RFC2, B and R. The relay circuit was isolated from the r.f. circuit by RFC1, RFC2 and C. The relay typically activated a paper chart recorder and a tapper (not shown). The tapper decohered the metal filings in the coherer to restore it to a sensitive (high resistance) state for the next signal.

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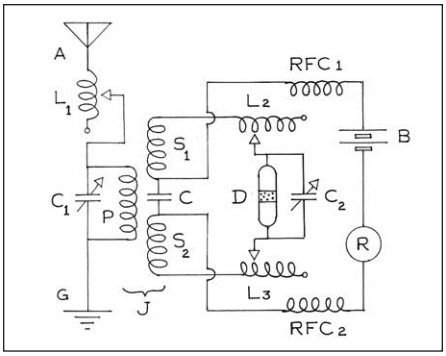

Fig. 2. Schematic of tuned receiver. The basic circuit is the same as the untuned one shown in fig. 1. L1, C1, L2, L3 and C2 were added for tuning. The circuits of Fig. 1 and Fig. 2 were adapted from reference [2].

Fleming, a prominent electrical engineer. The station employed a spark transmitter, but unlike its battery-powered predecessors it was powered by a 35 kilowatt alternator. Encouraged by ranges of several hundred miles obtained with the new station, Marconi decided to attempt trans-Atlantic transmission.

Most scientists of the time felt this was impossible. That opinion was based on the belief that radio waves, like light, should travel in straight lines, limiting radio communications to about horizon distances. Marconi knew that he had already exceeded that limit, and believed that radio waves, for some reason, followed the curvature of the Earth. Therefore he reasoned that with stations of sufficient size and power, he should be able to span the Atlantic. No one at the time knew that reflections from the ionosphere could greatly extend the range of radio transmissions.

Marconi chose Newfoundland as the receiving site for his first transatlantic experiment in order to minimize the length of the propagation path. In December, 1902, he sailed to St. John's with portable receiving equipment and set it up on Signal Hill, about 2100 statute miles, or 3500 kilometres, from Poldhu. The transmitting antenna at Poldhu was a fan, broadside to the Atlantic, made up of 54 vertical wires. The top of the fan was 60 metres (about 200 feet) wide, and was suspended 48 metres (about 160 feet) above the ground. The wires came together at the lower end where they were connected to the feed line to the transmitter. (See page 36 of Reference [3] for a good photo of it.)

The test schedule required Poldhu to transmit sequences of S's (three dots) in Morse code, together with short messages, interspersed with five-minute breaks at intervals. The transmissions took place from 11:30 a.m. to 2:30 p.m. Newfoundland time each day beginning December 11 [4]. The reported wavelength was 366 metres (820 kHz), and although there has been some controversy about this figure, it seems consistent with detailed modern analysis of the Poldhu transmitter [5,6].

Descriptions of the receiving equipment used are sketchy, and the details reported by different sources vary. I believe that the combined descriptions best fit two types of receiver developed by Marconi prior to 1900: an untuned receiver and a tuned ("syntonic") receiver. (See Figures 1 and 2.) Since there was no electronic amplification, the critical component in these receivers was the detector.

The detector used was called a "coherer," and there were two principal types. The best known of these consisted of a glass tube containing metal filings held between two metal plugs that served as electrodes. When a RF signal voltage was applied across its electrodes, the filings cohered, lowering the resistance of the device and causing the direct current in a battery circuit containing the coherer to increase.

This direct current typically operated a relay which fed a larger current to a paper tape recorder. The latter current also operated a tapper which decohered the filings after the receipt of each signal. Basically, the coherer acted like a voltage-controlled switch that closed when a radio signal was received. Many people were involved in the development of the coherer, including Sir Oliver Lodge, who gave the device its name.

In the second type of coherer, a drop of mercury was used in place of the metal filings. It was called a self-restoring coherer because it did not require a tapper. The behavior of this instrument is not well understood, but its detector action may have been principally due, like that of a diode, to its non-linear I-V characteristic. Although known as the "Italian Navy Coherer," this detector, used in conjunction with a "telephone" (earphone), probably was developed originally by Sir J. C. Bose of India [7]. Since there is a potential node and current antinode at the bottom of a grounded vertical aerial, Marconi stepped up the signal voltage applied to the coherer by means of a RF transformer, called a "jigger," in both his untuned and tuned receivers. The principal difference between the tuned and untuned receivers was that the primary and secondary circuits of the jigger were tuned in the former by means of variable inductors and capacitors, whereas no effort was made to tune the circuits of the latter.

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radios after I figured out where the local oscillator and mixer padder capacitors were. Someone had tightened down all of the screws on the two IF transformers on one set, and as a result it had several IF responses, none at the intended 455 Kc. I finally peaked the transformers at one of the stronger responses and then walked the adjustments up to the correct frequency.

The local oscillator and mixer adjustments were straightforward, and I set them at the top end of the band for correct calibration and best gain, respectively. The local oscillator also has padder capacitors for calibration adjustment at the bottom end of the two lower bands.

Mechanically the EC-1 is small—only 7½" tall, 10¾" wide, and 7½" deep. Its cabinet and chassis are made from the same grade of steel as used in its contemporary big brother, the SX-28, and its tube sockets are the same molded plastic. The parts are made by the same manufacturers as those in the SX-28; there are just fewer of them. To lower costs, the three local oscillator coils are all wound side-by-side on a single, sturdy cardboard-tube coil form, as are the three RF input coils. The bfo coil is wound on another cardboard form that is quite a bit thinner.

There is a compression trimmer capacitor, accessible from the back of the set, for adjusting the bfo frequency. And there are also two compression trimmer capacitors built into a single, sturdy, ceramic body to adjust the local oscillator tuning on the two higher-frequency tuning ranges. So while the EC-1 is a bare-bones radio, outside of the cardboard coil forms it was made of pretty substantial stuff. That's probably the reason why my two examples have survived this long.

Echophone ads, especially later in 1941 and afterwards, pitched the EC-1 as an ideal radio for the U.S. soldier or sailor to take along with him in the service. They featured a diminutive character named Hogarth—today he would be called a "nerd"—who was always coming out on top because of his EC-1. The admiral scrubbed the decks for him and pretty girls on a South Pacific island surrounded him to listen to his EC-1.

Since the EC-1 was one of the few communications receivers that appears to have been actually available after the war started, was low-priced, and was small and thus easily carried in a duffle bag, I would not be surprised if many of them actually did wind up being "entertainment radios" for our troops.

In 1945 revised EC-1A and EC-1B models appeared on the scene. They had a 12SA7 converter instead of the 12K8, and were physically identical, except for the paint job and name, to the Hallicrafters S-41G that came out later in 1945.

On the air, the EC-1 works amazingly well for what it is. I have one of my EC-1s sitting next to a window in my "great room" and attached to a 20-foot antenna strung up to a second-floor porch outside. As a casual receiver for AM shortwave broadcast stations and the gang on 75 meters it does a very passable job, given a few minutes to get warm-up drift out of the way.

All CW signals sound "hummy," about T-7, but at least they are copyable and the bfo is not swamped by strong signals. I can even make out 40-meter SSB signals with a little patient tuning. I think this little radio is still doing just what Bill Halligan intended for it to do when he brought it out in 1941, and that makes me feel good. It is indeed the first of "the radios that amazed the experts."

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Part 2 (conclusion): The Trans-Atlantic Experiments

We apologize for not mentioning in February that the installment of this article published then comprised only Part 1 and that the second and final part would follow in this issue.—MFE

On December 11, 1901, Marconi and his party used balloons to support the receiving aerial wire which was about 500 feet long. According to Marconi's assistant, George Kemp, "Marconi tried all the detectors from time to time" until a heavy gust of wind blew the balloons away, ending the day's experiment. "Signals appeared at intervals on a telephone in series, when using our sensitive tube (coherer) circuit, and, at times, the dots threatened to appear on the tapper." [8]. The receiver was the syntonic (tuned) type.

On December 12, a kite was used to support the aerial wire, and Marconi switched to the untuned receiver because the erratic changes in elevation of the kite made tuning the aerial too difficult. Later, in a recorded address, Marconi said that he "tried various microphonic self-restoring coherers placed in the secondary circuit of a transformer, the signals being read on a telephone. In many cases a succession of S's being heard distinctly (also heard by Kemp) although, probably in consequence of the weakness of the signals and the unreliability of the detector, no actual message could be deciphered. The coherers which gave the signals were one(s) containing loose carbon filings, another designed by myself, contained a mixture of cobalt and carbon filings, and thirdly the 'Italian Navy Coherer,' containing a globule of mercury between two (conducting) plugs" [4].

Marconi recorded in his diary: signals received at 12:30, 1:10, and 2:20 Newfoundland time [2]. Marconi said later "At 12:30 PM, while I was listening on the telephone receiver there came to my ear, very weakly, but with such clarity that there could be no possible doubt, a rhythmic succession of the 3 dots corresponding to the letter "S" of the Morse code..." [4]. Some signals also were received December 13 during the brief time that a kite could be kept aloft.

When Marconi announced his reception of trans-Atlantic radio signals to the world, the Anglo-American Telegraph Company, which held a monopoly on telegraphy in Newfoundland, threatened court action if Marconi continued his wireless work there. That ended trans-Atlantic radio experiments in Newfoundland. His announcement of success met with some scepticism, especially in England, based on preconceived notions about radio waves travelling in straight lines.

To counter this and fully satisfy the Board of his company, his next long range experiment was carried out on a voyage from Britain to New York aboard the *SS Philadelphia* in February, 1902. In this experiment, he continually monitored signals from the Poldhu transmitter, which was unchanged and still operating at a nominal 820 kHz (366 metres).

Judging from Kemp's description, the receiving antenna was a four-wire horizontal cage about 150 feet above the deck [8]. A syntonic (tuned) receiver was used. Morse code messages were received to a maximum range of 700 miles during the day and 1550 miles at night. The repeated Morse letter S (the test signal used in the Newfoundland experiment) was received up to about 2100 miles at night, approximately the distance from Poldhu to St. John's. Marconi tested the range of the Poldu station again in 1902 on voyages aboard the Italian naval vessel *Carlo Alberto*, presumably with a tuned receiver. The results were consistent with those obtained on the *SS Philadelphia.*

During a summer voyage around the European coast, signals were received about 1600 miles from Poldhu at night (not necessarily the maximum range), but only to about 500 miles by day. On an east-west trans-Atlantic voyage in October, signals were received right into the harbour at Sydney, Nova Scotia at night, at a reported wavelength of 1100 metres (about 273 kHz). Although these voyages vindicated Marconi as far as proving that trans-Atlantic radio communications were possible, they indicated that they could only be made at night at wavelengths of hundreds

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of metres, raising questions about the daytime experiment in Newfoundland.

Marconi was finding by trial and error that better results were obtained at longer wavelengths. He used a wavelength (at least sometimes) of 1650 metres (about 182 kHz) at his first trans-Atlantic station at Glace Bay, but still was confined to intermittent night-time operation. When he finally opened a commercial trans-Atlantic radio service in 1907 between another station near Glace Bay ("Marconi Towers") and Clifden, Ireland, he was using a wavelength of about 5000 metres (60 kHz). This provided reliable daytime communications and usable, but more variable night-time communications.

What does all this tell us about the first trans-Atlantic experiment between Poldhu and St. John's? Firstly, all the results obtained with tuned receivers were at least qualitatively consistent with modern experience and knowledge about radio propagation, although the long ranges obtained with such primitive equipment might come as a bit of a surprise to the reader [9]. Though daytime ranges at 820 kHz were limited to several hundred miles, the night-time ranges were several times longer.

The fact that no definite signals were received at St. John's on the tuned receiver (December 11) is no surprise to broadcast band listeners, and is consistent with radio propagation theory. According to the Austin-Cohen radio propagation formula [10], the daytime field strength at 820 kHz at St. John's would have been about 1/1500 of the field strength at the maximum daytime range achieved in the *SS Philadelphia* experiment.

The only result that seems inconsistent with modern knowledge was the claim of daytime reception of the 820 kHz trans-Atlantic test signal at St. John's on December 12, which was made with an untuned receiver. It has been suggested that Marconi may have mistaken atmospheric interference ("static") for the three dots of the letter S repeated continuously. I doubt this because Marconi was an experienced radio listener, and his description of the event, quoted above, sounds very convincing.

Assuming then that he did hear the test signal, the most reasonable explanation is that his untuned receiver detected it at some frequency or frequencies other than the nominal transmission frequency of 820 kHz. Spark transmitters were notorious for their broadband emissions, and it is quite probable that the spectrum of the Poldhu transmitter contained significant power in the HF (short wave) band. [5].

Propagation curves indicate that the daytime strength of a 7.5 MHz signal at St. John's would be about six times greater than the field strength of a 820 kHz signal 700 miles from a source of the same power (the maximum daytime range in the *SS Philadelphia* experiment), if ionospheric absorption is neglected [11]. However, only a fraction of the broadband HF spectrum of the Poldhu transmitter would likely reach Newfoundland; the ionosphere would absorb all of it except for a band a few MHz wide below the maximum usable frequency (MUF), which would have been about 12 MHz.

Add to this a host of more uncertain factors such as the relative performances at 820 kHz and HF of the transmitter, the antennas, and the receivers, and about all you can say is that spurious HF radiation from the Poldhu spark transmitter provides the most plausible explanation of the first trans-Atlantic radio transmission. Ironically, improvements in tuning prevented this from happening again in trans-Atlantic work, and the potential of short wave for long distance communications was not realized for another two decades.

REFERENCES AND ENDNOTES

8) Kemp, George, "Extracts from the diary of G. S. Kemp.," Vol. 3., *Marconi Archives*, Marconi plc.

(9) Typical ranges for shipborne 1.5 kW spark transmitters and receivers of the early 1900's (no electronic amplification) were a surprising 100 nautical miles at 1 MHz, and 185 nautical miles at 150 kHz. Factors contributing to such good results with such primitive equipment probably were: large receiving antennas with good ground connections to the hull of the ship, resulting in low antenna circuit losses; propagation over salt water; and the large impulsive power of a spark transmitter.

The voltage-controlled coherer detector was well suited to detection of the peak signals provided by the spark transmitter impulses. Ratcliffe (Reference 5) estimates the RF power output of the Poldhu transmitter during the damped wave spark impulses to have been a few tens of megawatts, whereas the average power input was only 35 kilowatts! This large ratio of impulse power to average power was due to the spark being produced by the relatively short discharge of a capacitor.

(10) P. David and J. Voge, *Propagation of Waves*, Pergammon Press, 1969.

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