The Spirit of Discovery

An Appreciation of the Work of Marconi

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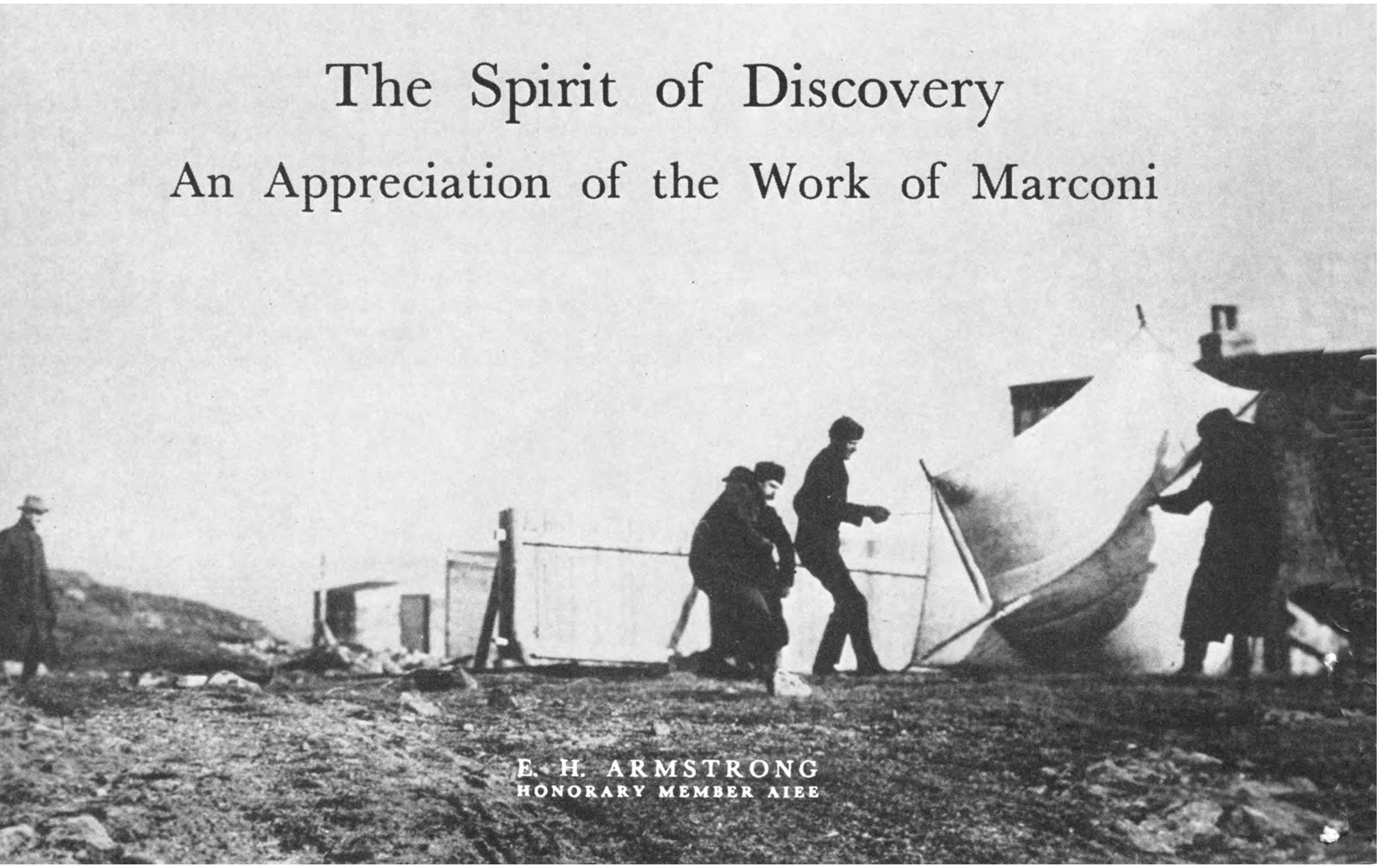

Courtesy of Canadian Marconi Company

It is not often that historical records show the name of a man credited with two basic discoveries. When a man has made three, then his attitude toward problems and how he solved them merit study. Major Armstrong makes such an analysis of Guglielmo Marconi's three great discoveries in the field of radio transmission and reception.

THERE IS an aspect of the history of great discoveries that has a way of repeating itself—they are often practically applied and utilized before the world of science comes to an agreement on the nature of what has been "discovered." A little over half a century ago, Marconi confounded the science of the time by demonstrating that electric waves, instead of following the laws that govern light and traveling in straight lines, could be made to follow the surface of the earth. He disproved that theoretical barrier to the usefulness of wireless so positively predicted by those who then claimed to understand the "laws of nature." While Marconi did not pretend to understand the phenomenon that he had uncovered, he knew what to do to apply it practically; and he created the art of long-distance signalling without wires. Years passed before the world of science reached agreement as to what it was that he had discovered.

We presently find ourselves in the same position with respect to some of the characteristics of microwaves. We are utilizing discoveries about the propagation of those waves, yet without any agreement as to the mechanism by which they are being transmitted. A set of circumstances such as this is not in itself too unusual. But when we look into the origin of the uncovering of the new phenomenon, we encounter an arresting fact—that it was once again Marconi who, making his third basic discovery in the field of propagation, pointed the way for us. It is seldom that a man makes two basic discoveries. When a man makes three, his attitude toward problems and his method of work merit the closest analysis and study.

All too little attention has been paid to Marconi's approach and his way of thinking, in part perhaps because of his own natural reticence, but mainly because there has been, in the United States at least, a widespread lack of understanding of the facts about Marconi's discoveries.

My old teacher at Columbia University, Professor Michael I. Pupin, paid tribute to Marconi's first great achievement on the gala occasion when the Institute

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welcomed him[1] after the historic reception of the letter "S" at St. John's, Newfoundland, Canada, from the Poldhu transmitter in the British Isles. It was my pleasure and privilege a few years ago to tell the story of Marconi's second fundamental discovery—that of the "daylight wave"[2]—when he found that if "short" waves were made short enough, the 22-year old radio axiom that transmission at night was superior to that by day had to be applied in reverse. On this occasion it is my purpose to pay tribute to Marconi's third great discovery, one made some 20 years ago, but whose significance we are just beginning to appreciate—that even the microwaves, or the Hertz rays of old, curve around the surface of the earth and may be detected far beyond the optical horizon.

In order to put the third discovery of Marconi in proper perspective the earlier discoveries and the work that led to them must be reviewed. That is especially appropriate because of the revival of the Popov claim in recent years in the journals of Soviet Russia. What did Marconi do to succeed where others had failed?

DISCOVERY OF THE "GROUNDED" WAVE*

At the beginning of his interest in the problem of signalling without wires, Marconi proceeded along what might be called conventional lines in his use of the "electromagnetic" wave, with experiments similar to those carried out by Hertz, Lodge, Popov, and other workers. The wavelengths used in that work were quite short, of the order of a few meters, and on occasion, in the centimeter range. Reflectors were characteristic of both transmitter and receiver. By the exercise of great ingenuity in design, and by what must have been consummate skill in the handling and operating of the equipment, Marconi succeeded in increasing the distances over which radio waves could be detected from a matter of a few hundred feet to several miles making use of devices that in form, at least, were essentially those of his predecessors. Optimistically, for Marconi was by nature an optimist, he ventured the hope to extend that range to the hundreds of miles.

Marconi's optimism was criticized by men who were quite sure they understood the laws of nature that applied. Marconi, they said in effect, if he knew the first principles of the electric waves with which he was working, would know that they had the same properties as light waves and so traveled in straight lines; hence, once beyond the horizon, transmission would be cut off. Had Marconi been more of a scientist and less of an inventor, he well might have agreed, concluded that his quest was hopeless, and stopped where he was.

He did not do that. Instead, in the face of the "scientific knowledge" of the day, he went forward with a painstaking series of experiments out of which came the discovery of a new principle. He learned how to attach his radiated electric waves to the surface of the earth by connecting his transmitter to an elevated and to a grounded conductor, and so to guide them around the earth's surface and on to undreamed of distances. He made that discovery, by proceeding in the face of all the rules set up by the "science" of his day.

* Subsequently named by Professor Pupin the "Marconi" wave.

Comment by one who had worked on the same problem contemporaneously with Marconi but unsuccessfully, is of greater value than that even of the historian, writing after time has silenced the voice of controversy. Hence, the words of Professor Slaby,[3] one of the founders of the Telefunken system, are particularly to the point:

"In January, 1897, when the news of Marconi's first successes ran through the newspapers, I myself was earnestly occupied with similar problems. I had not been able to telegraph more than one hundred meters through the air. It was at once clear to me that Marconi must have added something else—something new—to what was already known, whereby he had been able to attain to lengths measured by kilometers. Quickly making up my mind, I traveled to England, where the Bureau of Telegraphs was undertaking experiments on a large scale. Mr. Preece, the celebrated engineer-in-chief of the General Post-Office, in the most courteous and hospitable way, permitted me to take part in these; and in truth what I there saw was something quite new. Marconi had made a discovery. He was working with means the entire meaning of which no one before him had recognized. Only in that way can we explain the secret of his success. In the English professional journals an attempt has been made to deny novelty to the method of Marconi. It was urged that the production of Hertz rays, their radiation through space, the construction of his electrical eye—all this was known before. True; all this had been known to me also, and yet I never was able to exceed one hundred meters.

"In the first place, Marconi has worked out a clever arrangement for the apparatus which by the use of the simplest means produces a sure technical result. Then he has shown that such telegraphy (writing from afar) was to be made possible only through, on the one hand, earth connection between the apparatus and, on the other, the use of long extended upright wires. By this simple but extraordinarily effective method he raised the power of radiation in the electric forces a hundredfold."

What Popov failed to do was to learn how to attach his transmitted waves to the surface of the earth and so he failed to uncover that vital secret of Marconi's success.

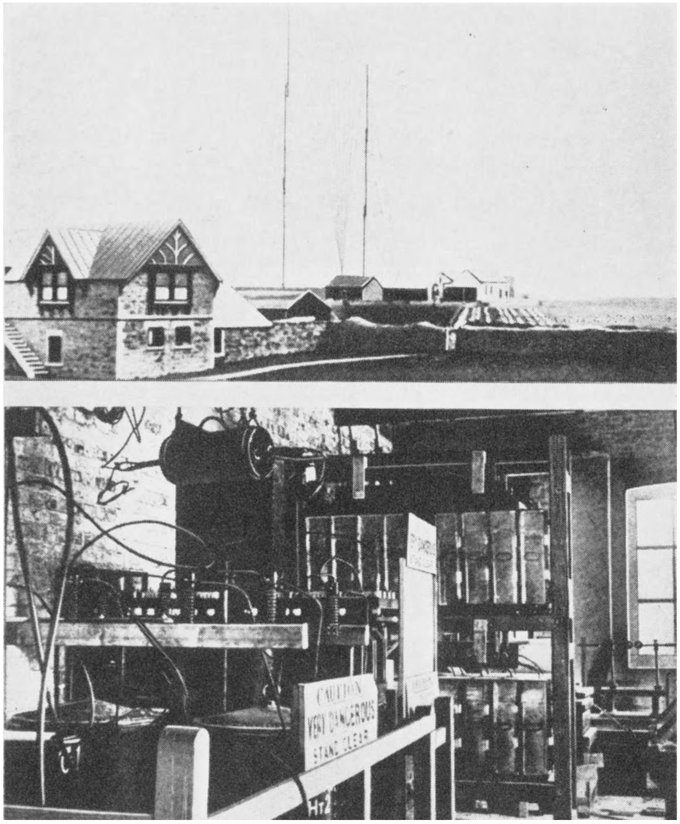
Marconi clearly realized that he had in his possession a new force, the nature and the bounds of which no one really understood. Although no range greater than a couple of hundred miles had yet been achieved, he conceived the bold project of attempting to span the Atlantic Ocean. With a transmitter of far greater power than any before constructed, but which could not have exceeded as an outside estimate 10 kw in the antenna, the attempt was made in December 1901, at St. John's, Newfoundland,† to receive the signals from the transmitter erected at Poldhu. See Figure 1. After some vicissitudes with balloon and kite supported antennas at St. John's, a 400-

† The St. John's site was selected as a substitute for the original plan to establish communication between stations which had been erected at Poldhu and Cape Cod, Mass. The elaborate antenna structures of 20 masts, each 200 feet high, were wrecked during the autumn gales in both places. Poldhu was equipped with a temporary and less effective antenna, and St. John's was selected on the basis of the shortest practical distance across the Atlantic and the freedom of undisturbed experimentation.

foot wire was kept aloft for sufficient periods on successive days to satisfy Marconi and his assistants that they had identified the Poldhu signals. See headpiece.‡‡ Controversy over the accuracy of Marconi's report continued for a time but the Institute accepted his statement and stood firmly behind him. Pupin's remarks recreate the atmosphere of the time. He said:

"......In scientific work we never believe anything until we see a demonstration of it. I believe that Signor Marconi has transmitted the famous three dots across the Atlantic but I must say I believe him because I know him personally. If I did not know him personally I would not believe him because the proof which Signor Marconi has furnished is not sufficiently strong from a purely scientific point of view; but knowing him personally as I do, I believe his statement."

In February 1902, the matter was settled when Marconi, aboard the steamship *Philadelphia*, carried the Poldhu signals out to some 2,000 miles with the limited receiving antenna facilities provided by the ship's masts. It was on that voyage that the difference in range between day and night signalling was first observed, the 2,000-mile range being obtained only during the hours of darkness over the transmission path. The daylight range was only a third as great. That observation was to have a profound effect on the course of the art. Subsequent experiments designed to narrow the gap between day and night ranges led to the use of successively longer wavelengths, and the trend away from the microwaves, which trend began when Marconi attached aerial and ground to his equipment, continued. It was destined to continue for over 20 years.



From "The Marconi Jubilee, 1897–1947"

Figure 1. Antenna and transmitting equipment used at Poldhu in 1901

The observations on the *Philadelphia* were followed by a long period of experimentation and construction, work that testified eloquently to a faith and a determination reminiscent of the faith and determination of those who laid the first Atlantic cable. Finally, in 1907, two transatlantic wireless stations with greatly increased power were completed and put in operation; one at Clifden, Ireland, and the other at Glace Bay, Nova Scotia. In these days, when millionfold energy amplification of the faintest of radio currents is a commonplace in home radio sets, it is in order to restore the perspective by pointing out that no faintest dream of an amplifier, even of the audible-frequency currents, existed to encourage the efforts of those who faced the problem of transoceanic signalling. The energy that moved the diaphragm of the telephone receiver was limited strictly to that which could be abstracted from the wave, an amount often so pitifully small that the act of breathing obliterated the operator's ability to perceive the signal. The next half-dozen years were the Dark Ages of radio communication, and Marconi, in common with others in the field, fought through them, until the appearance of the regenerative circuit, practical heterodyne reception, and the high-power arc and alternator, and ultimately the pure electron discharge vacuum tube, brought on the era of modern radio.

Then a new problem came into being—the problem of the static. So sensitive had receivers become that the feeblest of signals could be brought up to a readable strength and communication could be carried on over very great distances during periods of favorable transmission when static was absent. But when static was present, even on levels that previously would have passed unnoticed, it became evident that it was going to be the major factor limiting communications. So the art moved in the direction of still higher powers for transmitters, which meant still longer wavelengths where the static was worse and the size and cost of antennas was much greater.

By the end of World War I, large amounts of capital had gone into the development of high-frequency alternators in the various countries (Alexanderson in the United States, Von Arco and Goldschmidt in Germany, and LaTour in France) and the long-wave vacuum-tube generator was making its appearance in the British Isles. Waves of 10,000 meters were the order of the day; and to radiate them effectively, very costly antenna structure was required, some approaching 1,000 feet in height and a mile in length. The business of transoceanic communication could not be carried on without capital investments of major proportions. Powers of the hundreds of kilowatts and the improved receiving means made it possible to operate perfectly during the undisturbed periods of the early morning hours, but with the coming of atmospheric disturbances in the afternoon and evening, originating in the electrical storms of the tropics, reception from even

‡‡ Signor Marconi, extreme left, supervising the launching of the antenna-supporting kite at St. John's, Newfoundland.

the highest powered transmitters was frequently blotted out. During such periods the brute force method all too often failed to match up to the forces of nature.

We were quite satisfied with the working of our transmitting and receiving equipment, which operated well in the absence of disturbances; and the idea that we were doing the wrong thing never entered our heads. That there might be some way of working with an unknown force of nature, rather than against those presently known, appears to have been beyond the imagination of those in the art at the time. Another basic discovery was required to get off the dead-end road. Moving amidst a competition now increased multifold beyond that of his early days, it was nevertheless Marconi's destiny to make that discovery, but only after the chance to make it had been repeatedly missed—by him and others—for nearly 3 years.

DISCOVERY OF THE "DAYLIGHT" WAVE

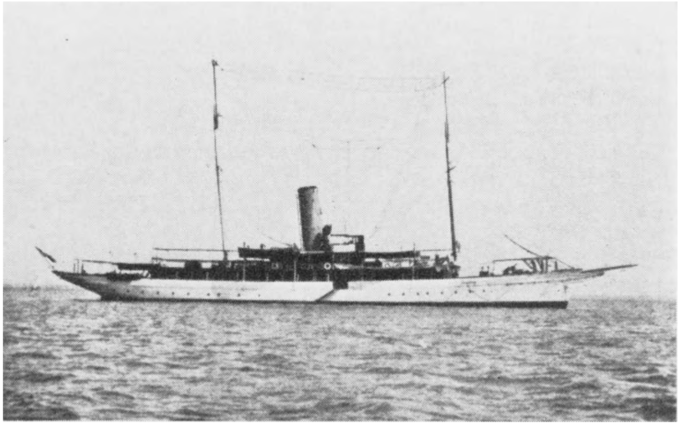
It was my privilege some years ago in a talk before the Western Society of Engineers to present the full story of that accomplishment, and the following account abstracts the essential facts from it.

The ending of World War I released the experimental energies of a very able engineer of the British Marconi Company, C. S. Franklin. Following up some work of Marconi for the Italian Army with short-wave directive beams, Franklin established a telephone circuit between London (Hendon) and Birmingham in 1920, on the extremely short wave of 15 meters. That wavelength was chosen, not for any expected advantage in transmission, but because it was easy to set up a reflecting antenna for waves of that order, and because loss of range, that is, the "daylight effect," does not occur over so short a transmission path (100 miles). The Hendon and Birmingham transmitters had effective radiated power of about 4 kw, and the system worked well. The significance of the Hendon-Birmingham circuit in this chapter of radio history will appear presently.

THE FIRST TRANSATLANTIC S-W SIGNAL

The radio amateur comes into the story at this point. American and British amateurs had been talking for years about organizing a test to determine whether the wavelengths on which they were allowed to work, the commercially "useless" ones of 200 meters and under, could span the Atlantic—during the hours of darkness, of course. Such a test was finally organized in 1920, on the amateur's standard wavelength of 200 meters. It failed. In the next year, another test was organized. Though all prophecies were that it too would fail, in fact a score of United States amateur call-letters were identified in the British Isles in December 1921, two of them from stations with power of less than 100 watts; and one of the stations, Station *1BCG*[4] in Greenwich, Conn., succeeded also in transmitting a complete message.

But the signals could be received only during the night hours of the Atlantic path; they ended with sunrise at its eastern end and did not reappear until after sunset at its western end. While the results caused a flurry of interest for a time, it soon died down. Though everyone was surprised that a 200-meter wave could span the Atlantic, neither the commercial companies nor those who took part in the tests were stimulated to investigate the shorter waves further. I had a hand in the construction of the *1BCG*[4] transmitter and also in the decision to dismantle it after the test, when the question of further investigation was discussed. But why investigate something with so fatal a defect, a telegraph system that could work only part of the time? Marconi seems to have been the only man in the commercial field whose imagination was fired with the spanning of the Atlantic by the stations of the amateurs.



From "Journal," Royal Society of Arts

Figure 2. The yacht Elettra on the voyage to Cape Verde Islands

In a paper presented before the AIEE and the Institute of Radio Engineers in New York, N. Y., in June 1922,[5] Marconi told about some of his recent work in radio, including the work for the Italian Army with directive beams and the 15-meter Hendon-to-Birmingham telephone circuit. He suggested that radio perhaps had gotten into a rut by confining practically all its research to the long waves, and that more attention should be given to the shorter waves; and he summed up his remarks on the subject with these prophetic words: "I have brought these results and ideas to your notice as I feel—and perhaps you will agree with me—that the study of short electric waves, although sadly neglected practically all through the history of wireless, is still likely to develop in many unexpected directions, and open up new fields of profitable research."

THE CAPE VERDE ISLAND CRUISE

Upon his return to England, Marconi began a series of experiments from the historic Poldhu site, which took him on a cruise in his yacht *Elettra* to the Cape Verde Islands in the South Atlantic during the spring of 1923. See Figure 2. He had set up a transmitter at Poldhu (see Figure 3) on the longest "short" wave for which it was then practicable to build a reflecting beam antenna, about 100 meters,§ with an effective power in the beam of about 120 kw. He listened to the Poldhu signals as he cruised south, and found them to be extraordinarily good at night. The daylight signals disappeared at about 1,400 miles but at night in the Cape Verde Islands over 2,500 miles from the transmitter, they were far better than any signals that ever had been received over a comparable

§ The Poldhu wavelength during this voyage was 97 meters.

distance from a high-power long-wave station. Marconi reported[6] that, even when the power at Poldhu had been reduced to 1 kw, the night signals were still better than those received from the highest powered transoceanic stations in the British Isles. While the usual disappearance of the signals during daylight hours occurred, Marconi observed that the signals lasted for a time after sunrise at Poldhu and became audible again before darkness had set in at the Cape Verde Islands. At that time of year, the sun rose at Poldhu about 3 hours earlier than at St. Vincent, where the yacht was moored.

Marconi's observation led him to suspect that some new phenomenon was present in the short-wave band, something quite different from the normal effect he had observed for years at sunrise on long-wave reception across the North Atlantic. After his return to England, he laid out a program of further experimentation for the following year, when he would compare the signals at 90 meters with those on a number of shorter wavelengths, down to the region of 30 meters. In the summer of 1924, he cruised through the Mediterranean to the coast of Syria; and in Beyrouth Harbor in September of that year, he made the astounding observation that the signals on the 32-meter wave from Poldhu, some 2,400 miles away, held in throughout the day;[7] that in fact they were as good as the nighttime signals, whereas a longer wave of 92 meters, on the same power, behaved as at the Cape Verde Islands. What Marconi was observing was transmission by reflection from that ionized layer of the upper atmosphere which later became known as the F_2 layer, after years of observations had laid bare the mechanism by which the effect was produced. But as with Marconi's first discovery, his practical achievement was years ahead of the theory.

Returning to England within a month's time, Marconi sent notification of scheduled transmissions on 32 meters to Argentina, Australia, Brazil, Canada, and the United States; and at the appointed times, the daylight signals were received in all those countries. From the end of the earth, Australia, came a report of successful reception for $23^1/_2$ hours of the 24.

These results become still more astonishing when it is remembered that Marconi was using only a small percentage of the power of the transoceanic long-wave stations, and was unable to take advantage of his directive beam antenna because of the diversity of the paths of transmission to the various receiving points.

As sometimes happens with radically new discoveries, the significance of Marconi's results was not generally appreciated, at first, outside his own organization. As in the case of his original discovery, what he had done was too far out of line with established teachings to be accepted in advance of a physical demonstration of the result. But while others hesitated, Marconi, supported by the brilliant engineering of Franklin, moved rapidly, and by the end of 1927 short-wave beam transmitters were operating between England and all the principal parts of the Empire, and at speeds (100 words per minute) that no long-wave transmitter or cable ever had approached. The long waves were obsolete; and the cables were on the way to becoming a secondary means of communication.

Today, all but a few per cent of the world's long-distance radio communication is carried out on wavelengths less than one quarter the length of the waves originally allotted the amateurs in the 200-meter range. Perhaps the best measure of the advance from the era of the "grounded" wave is that it is now commonplace for amateurs the world over, with a few hundred dollars worth of equipment, to communicate with one another, and the "working" of several continents in a single day is no longer the subject of comment.

Both the British Marconi Company and the Telefunken Company recently issued 50th anniversary books, beautifully illustrated with pictures of the high-power long-wave transoceanic stations of the early 1920's. A comparison of them with a photograph of a present-day trans-world short-wave station or even of a modern American amateur station testifies, more eloquently than any words can, to the power of the right idea.

MISSED CHANCES

We can return now to the Hendon-Birmingham beam already described and contemplate the moral of the

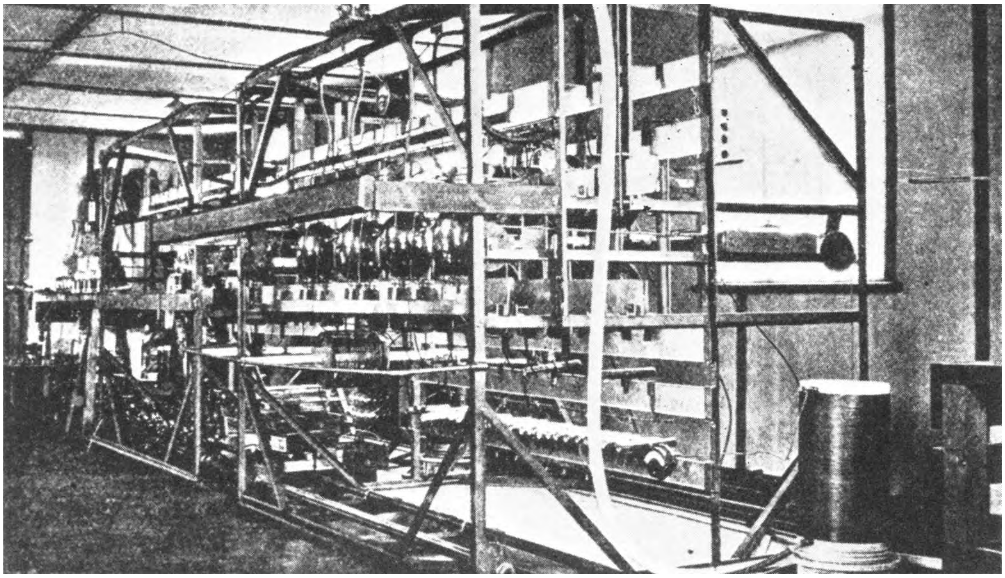
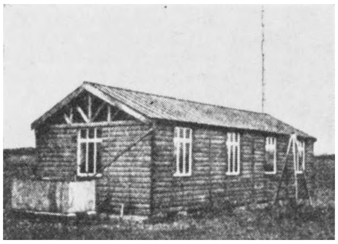


Figure 3. The Poldhu beam transmitter in 1923. The interior is shown on the left and the exterior of the experimental station is pictured below

From "Journal," Royal Society of Arts



story of one of the great missed chances of radio history, the chance that every American amateur and radio experimenter had had to tune in the Hendon-Birmingham beam telephone as early as 1922 and discover the daylight wave before Marconi. The Great Circle course of the Hendon beam lay across eastern Canada and the United States. The 15-meter wave, as was found later, was a better daylight wave than those in the 30-meter range, though it was not effective at night. Full information about the Hendon station was available from Franklin's and Marconi's publications, and all necessary information about the most effective means of receiving such waves, the superheterodyne, had been published.

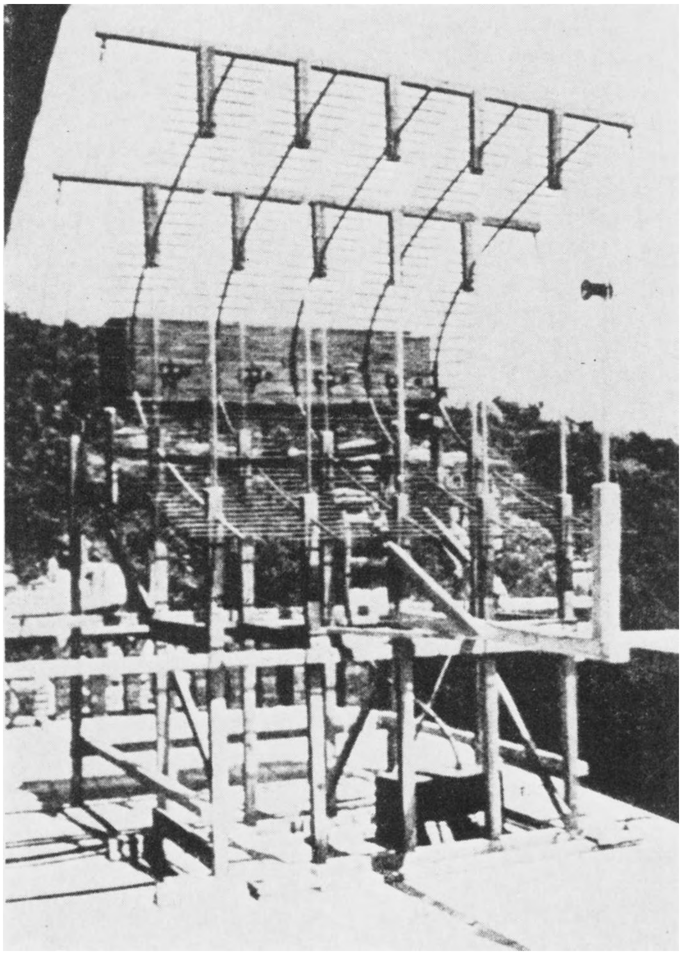
Had any radio experimenter in the United States thought to set up a superheterodyne for 15 meters and listen for the Hendon signals during the daytime, he almost inevitably would have heard them at some time during the day, and he, instead of Marconi, would have discovered the daylight wave. But no one had the imagination to set up a receiver and listen. We all "knew" too much about propagation; only a madman in those days would have proposed to receive 15-meter signals across the North Atlantic, especially during daylight hours.

There is, however, a consolation for the American experimenters who missed the chance. The master experimenter, Marconi, also missed it. Though for more than 20 years he had made it a practice on voyages to the United States to take along receivers to listen to his British stations, when he crossed the Atlantic in the *Elettra* in 1922 it seems not to have occurred to him to take along a 15-meter receiver and listen to Hendon. Had he done so, and turned the Hendon beam to follow the yacht, he would have discovered the daylight wave 2 years before he actually did.

It is important at this point to call attention to a strange and disquieting circumstance, the failure among our writers of history and our textbooks to tell the story of this great discovery correctly and to credit Marconi with making it. There are great lessons to be learned from his accounts of the two voyages of the *Elettra*, and the facts have been available, yet our literature on the subject has been either completely silent or downright incorrect.

Two outstanding instances appear from the history of this development which reveal Marconi's intuitive sense of what to investigate and where to look for new results. The crossing of the Atlantic by the large number of amateur signals, some of them of extremely low power, meant something more to Marconi than quite evidently it did to the rest of us. He went ahead with his investigation. His observation of the signals in the Cape Verde Islands revealed that the daylight fade and the nighttime rise did not behave in accordance with his previous experience with long-wave signals.|| In his July 1924 Royal Society paper the phenomenon was described, and in the discussion Marconi correctly diagnosed the limits of his own knowledge. He stated in response to questions that he did not know whether some other wavelength might not perhaps cover great distances in the daytime. So he made the experiment and found the answer. The rest of us knew too much about the laws of nature to try.

|| Sunrise at Poldhu occurred 3 hours earlier than at Cape St. Vincent.



From "Proceedings," Royal Institution of Great Britain

Figure 4. The 60-centimeter beam transmitter and antenna

THE "BENDING" OF THE MICROWAVES

THE THIRD TIME when Marconi pointed the way to a new form of propagation of electric waves was in the summer of 1932. A new approach to short-wave communication had been taken, with a microwave beam powered by a continuous-wave generator, in March 1931, when the Standard Telephones and Cables Company of London and Le Material Telephonique of Paris demonstrated communication across the English Channel (Dover to Calais) on a wavelength of about 20 centimeters. Radio was back in its original waveband, with its parabolic reflectors small enough to fit into an average sized room, but with the important substitution of the vacuum-tube generator for the spark oscillator and an enormously more sensitive vacuum-tube receiver for the coherer devices.

The increase in distance over the original microwave transmission range of a few miles was hardly as impressive as one might have expected, considering how far the art had advanced in 3 decades, although the reliability of the service unquestionably was. The cross-Channel work was accepted by the radio world for what it was—line-of-sight transmission following the characteristics of a searchlight beam; and when bad fading was encountered during certain meteorological conditions, the microwave region was definitely consigned to the field of short-range links.

It is not clear whether Marconi was actively working with centimeter waves at the time or was inspired by the success of the cross-Channel demonstration to look further into them. Whatever the motivating force, we find him working in the following year (1932), with the able assistance of G. Mathieu, with a 60-centimeter beam located on high ground in the vicinity of Rome, testing out for himself once again whether the "laws of nature" were as they were supposed to be. Once again we find in his account of his work the same painstaking experimentation, the same awareness that he did not know the answers, although others already were satisfied that they did. While others extrapolated observations into theories, Marconi worked with his apparatus and let the results speak for themselves. See Figure 4.

The only satisfactory continuous-wave generator available for the frequency with which he was working appears to have been the Barkhausen-Kurtz type; but the available tubes, when pushed for power, proved to have a life measured by minutes. Marconi had new tubes developed, adjusted to fit into circuits and to operate reliably with increased power. With several units in parallel, he appears to have obtained an effective power of the order of 10 watts. His receiver made use of an electron oscillator arranged for superregeneration. The gain of the parabolic reflectors used was given at 8 decibels.

With that equipment, which must have required the same consummate skill to handle as the original coherer spark equipment, he once more found that difference between experimental fact and accepted theory which he had encountered twice before. Having installed his transmitting equipment atop Rocca di Papa, an elevation of some 2,500 feet above the Mediterranean Sea, he steamed away on the *Elettra* through areas of varying signal strength receiving the last faint signals at a distance of 125 miles, where the receiving antenna was at least 1/2 mile below line-of-sight transmission. Continuing on to Golfo Aranic, Sardinia, he disembarked the receiving equipment and installed it on the tower of the signal station at Cape Figari, 340 meters above sea level. Although the distance was 168 miles, and the receiving station over a mile below line of sight, 100-per-cent intelligible speech was received during the strong periods of the signal, which varied in strength from completely intelligible reception to inaudibility in slow deep fades.

Marconi announced his discovery of the bending of the waves, but it was received with skepticism. The line-of-sight theory of transmission of centimeter waves was too firmly ingrained to be disturbed by one experiment, even when the experimenter was Marconi himself. I well remember that my own reaction to his announcement at the time was similar to that when the rumor of the discovery of the "daylight wave" was in the air. It was against the laws of nature as I knew them, and hence it was not conceivable that it could be true. Perhaps some of the rigidities of the mind of the engineer would be eased a bit by more frequent reference to a few words set down some centuries ago: "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy." (Hamlet) Today, we know Marconi was right; but nearly 2 decades passed before the words of his prophecy at the time came true. Ill health and the end of his career terminated further exploration of the new mode of transmission; but he left the vision, and his own words present it as he saw it. In the conclusion to his paper[8] he said:

"In regard to the limited range of propagation of these microwaves, the last word has not yet been said. It has already been shown that they can travel round a portion of the earth's curvature, to distances greater than had been expected, and I cannot help reminding you that at the very time when I first succeeded in proving that electric waves could be sent and received across the Atlantic Ocean in 1901, distinguished mathematicians were of the opinion that the distance of communications, by means of electric waves, would be limited to a distance of only about 165 miles. H. M. Poincare—Notice sur la telegraphie sans fil. Annuaire pour l'an 1902 des bureaux des longitudes—Paris."

When we remember the low power available for transmission and the crudeness of the equipment with which Marconi accomplished the 168-mile transmission, and consider the incomparably superior equipment that has been available to us from the technical developments of World War II, the wonder is that his prophecy went so long unheeded, and that the investigations of the past few years were so long deferred. Certain it is that, with the tools at hand, we have taken a long time to catch up with the prophecy.

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Gas Turbine for Compressed Air

A 1,800-horsepower gas turbine-compressor has been installed in a trailer for tests to determine its suitability for supplying compressed air. The gas turbine, two multistage centrifugal air compressors, a 50-horsepower starting motor, and a 60-kw generator and auxiliaries are mounted on a fabricated steel bedplate. The plant requires only two external connections for starting, electric power for ignition and motor-driven auxiliaries, and distillate fuel for the gas turbine. The open-cycle gas turbine develops more power per unit of weight and volume than any other type of prime mover and is ideally suited for a mobile unit.