# THE GREAT NOBEL PRIZES

# GUGLIELMO MARCONI

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BY
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# EDITOR'S FOREWORD

In 1909 Guglielmo Marconi and Ferdinand Braun of Germany were jointly awarded the Nobel Prize in physics *in recognition of their services in the development of wireless telegraphy*. This wording suggests that Marconi did not *invent* radio, as is so often thought, but helped to develop it. This in a sense is true. When Marconi was a boy at school the brilliant German scientist, Heinrich Hertz, first demonstrated conclusively the existence of radio waves, and Marconi's own early work in radio was to a certain extent paralleled by Popov in Russia and by Braun himself as well as others. Yet it is to Marconi almost entirely that we owe the present world-wide importance of radio. There can be no question that Marconi was indeed "the father of radio."

He had several important assets that put him head and shoulders above his colleagues in the field. Although self-taught, he had a remarkably intuitive mind, a mind that could grasp the essentials of a problem and see what needed to be done. "He did not unlock the secrets of radio by exercise of some superior reasoning process" E. H. Armstrong, himself a pioneer of radio, wrote later. "He studied the phenomena of radio as he encountered them, with an enquiring and open mind; as he let Nature and his apparatus get the answers for him."

Marconi moreover had the virtue of dogged persistence. When he was a boy he astounded his young cousin, Daisy Prescott, by putting a needle and compass into motion with radio waves directed across his room. From that point until his death in 1937 all his energies were focussed upon the single problem of how to propagate radio waves at a distance. By 1901 he had successfully thrown his radio waves across the Atlantic. Later—and long after he had won the Nobel Prize for his earlier work—he had, by means of short-wave, made world-wide radio communication a reality, and had even demonstrated the possibility of radar and of television.

The rest is history. Radio today has not only reached the moon, but underlies the entire structure of our technological civilization. Indeed, as Mr. Gunston points out, without radio the world as we know it today would be unthinkable.

Courtlandt Canby
Editor of the Series

# PART
# I

## Chapter 1

# THE BOY INVENTOR

No great scientific advance recognized by the awarding of a Nobel Prize has had more far-reaching and lasting effect on the whole of mankind than that achieved, and most significantly, developed as a practical reality by Marconi.

Guglielmo Marconi, father of modern radio and television and pioneer in worldwide wireless communication, who was awarded (jointly with Professor K. F. Braun of Germany) the Nobel Prize for Physics in 1909, was born on April 25th, 1874 in the Palazzo Marescalchi, Via Tre Novembre 5, near the centre of the beautiful city of Bologna, in Northern Italy. He was his parents' second child: they already had one son, Alfonso, who was born nine years before. To them, he was a long-wanted addition to their family. To the contemporary world beyond Bologna and its outskirts, his birth meant nothing. Yet the new arrival was to begin a completely new era in human history.

It has been said that to find the key to any great man, one must look at his mother. This is certainly true of the woman who lay in labour that fateful sunny morning in the lofty bedroom of the old Italian palace that stood on its own private square. Although her second confinement, it was a long and difficult one that nearly cost her her young life, but characteristically in later years she recalled of that day chiefly the golden glint of the sun on the nearby roofs and the hushed silence of the great house, with the doctor coming and going quietly and all the servants moving about whispering and on tiptoe, a quiet broken insistently by the persistent metallic barking of a far-off dog. That, and the blunt but significant comment of the old family gardener when, after the birth of her son, the household tension lifted and all the retainers assembled in her bedroom to join in the rejoicing and glimpse the new baby: "*Che orecchi grandi ha!*"—"What big ears he has!". To which, as the family legend has it, she replied in an intuitive flash: "He will be able to hear the still, small voice of the air." As a glance at any of the many photographs of Marconi will show, he retained this marked physical characteristic all his life, and linked as it was with acute and perceptive hearing, it seems a particularly apt one for a man destined to enable people to hear one another as never before, across unimaginable distances.

Marconi's mother was born Annie Jameson, the fourth and youngest daughter of Andrew Jameson, a Scot who had migrated to Dublin with his older brothers where they founded the Dublin Brewery, and where later he set up his own whisky distillery. He had an old manorial home, Daphne Castle, County Wexford, and ruled his family with the traditional Victorian rod of iron. But he had reckoned without Annie, a dark, lively, blue-eyed girl of immense charm and self-will. Like Bathsheba, the heroine of Thomas Hardy's *Far From the Madding Crowd*, "She was of the stuff of which great men's mothers are made." Related on one side of her family to the Scottish clan of Haig, which meant that her famous son had ties of kinship with the controversial British military leader of World War I, Earl Haig, she was short, with glinting auburn hair, strong features, an even stronger will, and a musical Irish voice. She had taken singing lessons and as a girl in her 'teens was sufficiently accomplished to be offered a chance to sing before the public in London at the Covent Garden Opera House. On this occasion, however, her father had his way. With unfeeling lack of understanding he absolutely forbade the girl to do any such thing: for many such families in the mid-1800s, the merest thought of the theatre in any of its forms spelt an immoral world in which no well-bred young woman could possibly have any interest whatever. Nevertheless, the Jameson family succumbed to their daughter's pleading sufficiently to allow her a very worthwhile, and as it turned out, far-reaching consolation. They agreed to let her go to Italy to study the *bel canto* style of singing.

So, probably to her own amazement, Annie became a student at the Bologna Conservatory. She was to find not only music, but love. The Jameson firm did much of their Italian trade through a Bologna banker named de Renoli, and it was arranged that Annie should stay with the de Renolis whilst in that city. A few years earlier, in 1855, de Renoli's daughter Giulia had married a man of a good landed family, but in that same year she had died following the birth of their son, Luigi. The young widower met the attractive young Scots-Irish guest at his in-law's house, and the young couple fell wildly in love at once. His name was Giuseppe Marconi.

The Marconis were a tough country family who stemmed originally from high up in the Apennines. They were rather austere folk, comfortably off though not rich, managing their own farm and forest land with stubborn skill. Giuseppe was destined for the Church, was educated by priests to that end. But he proved to have no vocation, and his younger brother took holy orders instead. Giuseppe was given the chance of managing the family estates, but he preferred to move down nearer to Bologna, set up his aged father Domenico in the handsome Villa Grifone at Pontecchio, some eleven miles outside the city, launch him into a highly profitable silkworm-breeding venture, and himself manage with notable success the rich rolling fields and vineyards that went with the noble old house. In time, Domenico died leaving everything to his worldly son, and Giuseppe was able to live comfortably off his estate, and acquire as a town house the Palazzo Marescalchi.

Annie was prepared to forget her aspirations in music and naturally wanted to marry the man she loved. For his part he wanted the charming foreigner as wife, and as a mother for his baby son. However romantic the situation may have seemed in sunny Italy, in damp Dublin it looked decidedly risky. To the stern, unbending Jamesons, Giuseppe Marconi was just about the last suitor they would have chosen for their daughter. A man seventeen years her elder who had been married before and had a young child, a foreigner who could speak little English, and worst of all, a Roman Catholic (Annie and her family being Protestants). There could only be one answer to the whole mad idea, and Mr. Jameson gave it. Annie returned to Ireland, dutifully accepted the attentions of eligible young Irish swains—and waited. In a few years she would be of age, and free to follow her heart. The couple corresponded secretly, and the widower waited until he could claim Annie as his bride. In

April, 1864, the happy day arrived, and having travelled up to the English Channel coast by coach, Giuseppe met Annie at Boulogne and they were married at once. He took her back to the house in the centre of Bologna, where every year after her elopement Annie preferred to winter as the chill winds blowing over the hills of Pontecchio always affected her health.

Thus it was that the Palazzo became the birthplace, ten years later, of Guglielmo Marconi. The father must always have seemed an old man to the boy, but his business prowess and the esteem in which the neighbourhood held him proved compensations, enabling the embryo inventor and scientist to enjoy a leisurely, comfortable childhood, most of it spent at the Villa Grifone.

From his father, Marconi inherited his excellent business sense and his flair for taking just the right commercial action at the right time; his gift for useful publicity, for presenting a favourable image to the world; his peasant stubbornness; his serious attitude to life and his unwavering and amazingly patient attention to detail at all times; his refusal to be downcast in time of disappointment and disaster; his gift of inspiring the confidence and loyalty of helpers and fellow-workers, and his intense patriotism.

From his mother, however, he inherited his deep love of music; his refusal to be bound by other people's ideas and limited horizons; his sensitivity; his iron determination and self-will; his artistic self-absorption; his sheer drive; his vision and his genius.

Judged by modern standards, Guglielmo's education and early years were unorthodox, even odd. He received very little formal schooling and spent the greater part of many years cut off from youngsters of his own age, happily retreating into his own world of imagination and self-sufficiency. Of his childhood he himself admitted: "I was not a good boy. It seemed I was restless. In any event, I was always in some scrape." Annie Marconi herself taught him music and gave him religious instruction, insisting that he read the Bible every day when old enough and even reading him as much as two chapters daily. She must at times have felt strongly the contrast between him and her first child, Alfonso, who was always neat, clean, tidy, studious and obedient, but this did not stop her from always regarding Guglielmo as her unshakable favourite of the three boys she brought up. This was indeed fortunate, for without his mother's encouragement, support and faith he would never have been able to continue to pursue his vision, a quest for mastery of the ether that began in the big rooms and leafy grounds of the Villa Grifone.

Always something of a delicate lad and a lone wolf by choice, Guglielmo early found the delights of wide reading, happily browsing in the excellent library at the house, first digesting the Greek classics of mythology and history (the story of Achilles was his favourite), then on to lives of great world figures like Napoleon, Washington, Garibaldi and Benjamin Franklin (another favourite hero). Franklin kindled his interest in science, and soon he was reading all he could on chemistry and electricity and the work of discoverers like Faraday and Edison.

Although a stern disciplinarian and rather unbending with his young sons, old Giuseppe was not without charm or wit, but these were qualities that were lost on his offspring during their early days. Happily, the old man had a vast pride in Annie, and the good sense to allow her much freedom to bring up Guglielmo in the way she knew instinctively to be best. She could see that one of the boy's most unusual faculties was an almost superhuman gift of intense concentration, and she had the good sense to leave him alone with his thoughts. "If only grown-ups understood what harm they can do children," she said once in later years to her granddaughter, "They think nothing of constantly interrupting their train of thought." It was probably as an instinctive protection against his father that Guglielmo cultivated the mask of withdrawn reserve he was to wear all his life. Only a few intimates were ever to pierce that mask: but for Annie Marconi it

1 Marconi as a child with his elder brother, Alfonso, and their mother. In later years, when Marconi's invention was turned down by the Italian government, his mother gave him her full support and brought him to Britain and to fame.

Lecture & Practical Demonstratior

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MARCONI AND HIS MARVELLOUS APPARATUS.

How to Send Telegrams through Space and Apparent Obstacles will be demonstrated during the course of the Lecture. Mr. LYND will be assisted by Mr. W. W. BRADFIELD, one of Signor Marconi's Experimental Assistants.

2 A poster of 1897 advertises a lecture by William Lynd on Marconi and his invention. Thanks to the useful introductions his British cousins had arranged for him, Marconi's wireless had already won acclaim shortly after his arrival in the previous year.

never existed. The warmest and closest of bonds grew up between them that Giuseppe's anger, biting tongue, heavy hand and increasing meanness over petty matters could never sever. We cannot blame the old Italian countryman too much: his whole world was completely alien to the vision and the sensitivity of his youngest son. To him scientific experiments were a shocking waste of time and materials unless they immediately and obviously brought commercial gain, which of course they did not. Even Guglielmo's almost perfect English, learnt from his mother and soon to stand him in good stead once his life work began in earnest, alienated him from his elderly father, who contrasted it unfavourably with his much poorer Italian.

Annie tried to improve the situation by engaging a local grammar-school teacher called Germano Bollini to teach the two younger boys fluent Italian. But Guglielmo had little taste for Bollini's pedantic tuition and rebelled once again. All his life he was to hate discipline and formal restrictions of any kind, and his home lessons, sporadic though they were, proved constant thorns in his young flesh. Various tutors did their best, but scientifically speaking at any rate, Marconi could have justifiably claimed to be largely self-taught. He never received any formal scientific training, and it is arguable that if he had, his work might not have been so successful, since he would have been more trustful of other people's often wrong or inadequate conclusions, and less trustful of his own native intuition.

During some of the years of Marconi's childhood his mother' health was far from good, and the usual winter migration to the big house in the centre of Bologna was insufficient to spare her the rigours of the bitter north Italian winters. So the family moved temporarily further south to Leghorn or Florence, and during such winters there were spasmodic attendances by Marconi at local schools. In Florence, when he was about twelve, he went for a time to the Cavallero Institute, where he had his first serious training in chemistry and physics. He found the discipline harsh and daunting, and the experience made him even less gregarious than he was by nature. But he did make one friend at this school who was to remain so for the rest of his life, the first of the few close associates whose loyalty to the inventor remained undimmed through many vicissitudes.

Luigi Solari was an older lad, but he swiftly succumbed to the strange and compelling personal magnetism of Guglielmo, believing him to be a born scientific leader. In fact, before they were both out of their 'teens, Solari began the admirable habit of noting down the many and varied talks he had with Marconi. In those first days at Florence, however, his main impression was of a fellow-pupil who "was slender and delicate and habitually wore a stern expression." Unlike his other contemporaries and the masters at the school, though, Luigi Solari was not deceived by this rather forbidding facial expression. He knew it was merely a mask to conceal extreme shyness and uneasy nervousness. The following year the Marconis wintered at Leghorn, where Guglielmo was entered at the Technical Institute and was much happier, concentrating more on the scientific studies that meant everything to him already. For the first time, he began to do well academically, thanks largely to the exciting and sympathetic physics lectures of Professor Giotto Bizzarrini.

These formative years were not all scholastic boredom and self-centred scientific study and experiment, although the latter took up an increasing proportion of the lad's waking hours. There were other pursuits and much fun, some of it with other youngsters, neighbours in Leghorn, cousins and other relatives. There was lots of sailing, Guglielmo having mastered the art of sailing a small boat in the inner harbour at Leghorn when only nine. There were long trips into the beautiful countryside, many of them with Alfonso or Luigi Solari. There was always music, with Guglielmo at an early age a nimble pianist and Alfonso a not untalented violinist, and many visits to the opera with their mother. There was much delight, too, in the company of a young cousin, Daisy Prescott, whose father, General Prescott, was serving Queen Victoria in India, and whose mother, a sister of Annie Marconi, had settled for a time in Leghorn, partly to be near Annie and partly to take cures at the old Roman spas in the area. Through Daisy Prescott's keen and affectionate eyes we see very vividly the withdrawn young experimenter at close quarters, the self-styled "amateur of electricity" at work whilst still only a mere boy.

Although he had a willing helper in his experiments in his brother Alfonso, and occasionally in the more staid half-brother Luigi, not to mention the servants and estate workers and boys who all loyally lent a hand when required, Marconi seems to have shown Daisy work he was doing and talked to her of ideas he was brewing up that he kept secret from everyone else. Writing in later years of those days, she said: "During that time he had no teaching on electrical subjects, and used only to read any book or paper he could get hold of. Yet nothing else occupied his thoughts. His chief idea was to invent, and he used to say to me: 'Daisy, if you could only know what a lot of ideas I have got in my head.' He was never tired of trying to invent something, even when he was quite a little boy, and he used to come to his mother, saying, 'Come, Mamma, and look what I have made in the garden.' I remember when he was a lad of thirteen, his bringing me into a secluded part of the grounds (of the Villa Grifone) to show me how he could distil spirits. 'You see I have to keep the stuff boiling always, or it won't come right,' he said seriously." Obviously his Jameson ancestry sometimes came to the fore!

On another occasion, Miss Prescott recorded: "I remember going to see my aunt one afternoon, and finding Guglielmo sitting by himself with a huge pair of scissors, cutting some very thicklooking wire into pieces of about an inch-and-a-half long. His pretty fair hair was tossed, and his clear keen blue eyes were shining! Although outwardly calm, I saw he was deeply interested in his work. "Well, Guglielmo, what are you making now?' I asked. 'Is this your new invention and what is it to be?' 'You will see when it is finished,' he answered quietly, and this was all I could get out of him. He never would talk about what he wanted to invent. He managed to cut a piece of soft flesh out of his finger with the treacherous pair of scissors, so he put it away in a box, and said he would get it stuck on by and by, as a chemist did not live far off."

Later, she was to witness one of his first really significant experiments: "About a year and six months after this we all went up to

Grifone from the Baths of Lucca, where we had been passing a few weeks, and the morning after our arrival we found our way upstairs to the top of the house where Guglielmo's work-room was. I looked round. In every direction there were white jars and curious-looking pots full of water, etc. 'Well, Guglielmo, there is nothing much to see here. What have you invented?' I asked. I have forgotten to mention two curious carved pieces of wood which I saw lying in the next room, covered with tin, and which Guglielmo called 'reflectors'. 'Well, come and look here,' said my cousin. 'Do you see this needle?' On receiving my answer in the affirmative, he added: 'Then look, I will put it on this table.' He then took a small mariner's compass and put it at the opposite side of the room where the needle was lying, saying: 'Now look, I will make this needle move without touching it.' I looked well to see that there was no wire near the needle, or anything to connect it to the compass. Guglielmo then seated himself before an ordinary electric pear-shaped glassbulb (the ones we see daily) from which a blue light played. He touched the small globe, and in an instant both the needle and the compass began to move instantaneously.

"The other girls and I, who were in the room watching this simple but wonderful experiment, were all vastly surprised. At first I could not believe my eyes. I walked from the needle to the compass, and tried in vain to find a very fine wire (even as fine as a hair) in communication, but there was simply nothing. I thought Guglielmo was joking and in a moment we would hear a burst of laughter and see him thoroughly enjoying my stupidity, but nothing of the kind happened. He was in fact more than ordinarily serious and quiet, and seemed to be pondering over something. At last we were all convinced, and very much delighted. At lunch my enthusiasm knew no bounds, and we all wanted to know everything about the new invention, but though Guglielmo was always most kind in his answers, he was very modest and when I loaded him with praise he would answer: 'Now, be quiet, you think too much of me.' "

In later years Marconi revealed that the secret of this experiment was at that time the greatest of his life, so Daisy Prescott was indeed privileged to witness it. His apparatus was in fact a simple radio oscillator. With the aid of two reflectors actually made of zinc, not tin, he was in fact sending wireless impulses across the room. Gradually but inexorably, he was to increase the distances across which these impulses worked.

Earlier there had been many other experiments that were interesting, if less astonishing. Guglielmo several times had tried to emulate

Benjamin Franklin's highly dangerous method of drawing down static electricity from a thunder-cloud. Franklin used a flying kite to show how "electrical fire might be drawn silently out of a cloud," but Marconi rigged up a spear-like zinc conductor on the roof and connected it to a small bell inside the house. When sufficient static electricity was gathered during a storm, the bell could be induced to ring. Needless to say, however, the contraption was often rigged ready for action but no thunderstorm came, and on one such occasion when other boys jeered at his silent bell, he "closed up like a clam and went fishing." A characteristic reaction, since the patient, contemplative art of fishing appealed to him greatly.

Another time, neighbours at Pontecchio reported to old Giuseppe that they had seen Guglielmo rig up a line of china dinner-plates on a wire like so much washing strung along the bank of a stream in the Grifone grounds. He then passed a high-tension current from batteries along the wire—another experiment first devised by Benjamin Franklin. Unfortunately, this was only too successful for at the moment of switching on, the plates were flung from the wire with great force, ending up in pieces on the rocks beneath. This senseless and wanton damage of valuable property, which is what it seemed to the old man, was too much for Giuseppe. Henceforth he decreed that all scientific experiments at the Villa Grifone must cease, and he went round deliberately smashing all his son's apparatus in the grounds and outbuildings and in the two big third-floor attic rooms allocated to Guglielmo for his work by Annie.

Marconi's mother never lost faith in her son, even when her husband stormed and refused to allow any more money to be spent on such footling nonsense. She calmed the old man as best she could, and although she did not then fully understand what Guglielmo was trying to do, she realised instinctively that he was no ordinary youngster and needed every possible encouragement. She decided that his winter education at Leghorn should be supplemented by a special course of lectures by Professor Vincenzo Rosa, of the Niccolini College there. Rosa was a brilliant teacher, and Marconi always valued what he called "the clear and practical method with which Professor Rosa started me in the study of electro-physics." After that, she used her persuasive Irish tongue on a near neighbour at Pontecchio, the great Professor Augusto Righi, of the University of Bologna, who had long been studying the possibilities of what were then usually known as Hertzian waves.

Annie arranged for her son to attend some of the professor's lectures at the University, although he never matriculated and enrolled as a student there. Righi was helpful but not very enthusiastic: he could see nothing new in young Marconi's ideas and tried to steer him off the subject. But he did allow the lad to borrow books from the University library, and eventually to rig up some of his equipment in his own laboratory there. Righi's coolness merely spurred Marconi on to even more determined and concentrated effort. His feelings at this time were clearly described in a lecture many years later, when he said: "It seemed to me that if the radiation could be increased, developed and controlled, it would be possible to signal across space for a considerable distance. My chief trouble was that the idea was so elementary, so simple in logic, that it seemed difficult to believe that no one else had thought of putting it into practice. I argued there must be more mature scientists who had followed the same line of thought and arrived at almost similar conclusions. In fact, Oliver Lodge had, but he missed the correct answer by a fraction. From the first the idea was so real to me that I did not realise that to others the theory might appear quite fantastic."

Looking out over his lands from the Villa on those long summer days, old Giuseppe saw the strange being who bore his family name pacing up and down pondering his weird thoughts, or else crawling or climbing engrossed in some strange, unworldly experiment, wasting the time of the estate-workers and often causing the normally much more sensible Alfonso to dance about under the chestnut trees "as if he were possessed of devils," signalling to Guglielmo that some impulse or signal had been safely received at his end of the apparatus. No wonder Giuseppe kept saying: "His head is full of fantasy. One wonders that it ever occurred to him to think about eating or sleeping." And this was the son who now clearly was never going to enter the Naval Academy, as he had once hoped, or the University, or even take a serious hand in managing the estate. Giuseppe fumed or sulked. Annie acted as quiet encouragement, as peace-maker and go-between, easing the now really harsh financial stringency with which her husband was trying to punish the son who seemed to be deliberately going against everything he held dear, often placing meal-trays on the floor outside those attic rooms so as not to disturb the tyro scientist within. Looking back to those days from the years of fame and fortune, Marconi declared "*Ma non mi persi di coraggio*"—"But I did not lose my courage."

Matters came to a head in the year 1894, when Marconi was twenty. He spent a summer holiday in the Italian Alps with Luigi and Alfonso, and one day, whilst relaxing at a tiny, remote village called Santuario di Oropa in the Biellese mountains in Lombardy, he happened to pick up a copy of an Italian electrical journal (such literature being now his favourite reading) and began to read an article by his teacher Professor Righi on the work of the German physicist Heinrich Hertz, who was the first man really to detect and produce the electromagnetic waves that came to be named after him and which are now universally known as radio waves. Marconi himself takes up the story: "The idea of transmitting *messages* (author's italics) through space by means of etheric waves came to me suddenly as a result of having read in an Italian electric [sic] journal about the work and experiments of Hertz. It was a long and interesting article; Hertz had just died—actually in the preceding January. The idea obsessed me more and more, and in those mountains of Biellese I worked it out in imagination. I did not attempt any experiments until we returned to the Villa Grifone in the autumn. There I began experiments in earnest."

Signalling, making lights flash, needles jerk and bells ring—that was one thing, but it is clear that on that day in those lovely mountains Marconi first conceived the idea of sending messages by wireless. The rest of his life was to be dedicated to that proposition.

Already, the Fates had been kind in filling in the one small but vital gap in the young man's disjointed training for his life work.

One summer, years before at Leghorn, Guglielmo had encountered a kindly old man named Nello Marchetti, who was going blind. The boy spent many holiday hours reading to the man, who by happy chance had actually been a telegraphist in his younger days, and perhaps by way of gratitude for the lad's kindness, perhaps sensing through their talks on the marvel of electricity that practical help was called for, Marchetti taught him the Morse code. On a Morse tapper, set on a windowsill, Marconi learnt in a few days the famous code to which he was soon to give new and unexpected wings.

During the winter of 1894-95 the experiments continued, meeting with a steady but not unbroken success. "A problem is always simple —when solved," as Marconi said afterwards. "To radiate was not easy, and there were a thousand and one things to make the pioneer's path difficult. From the beginning I aimed at interfering with the radiation from the oscillator, breaking the emission up into short and long periods, so that the semblance of a 'dot' and a 'dash' could be transmitted. It was in December, 1894, that I first succeeded with my radiation problems. The winter was severe, but my mother decided that she would stay with me at the Villa Grifone, so that she could be near me at my work; she was deeply interested in all the work I did and every step of progress which I made, however small and apparently unimportant it might be."

In after years Signora Marconi never tired of telling how, one December night after she had gone to bed leaving Guglielmo still at work in his attic, and had in fact been asleep for several hours, she was awoken by his urgent hand on her shoulder. Candle in hand, tired and dishevelled, he was impatient to show her something. "Come, mother," he said, "let me show you." Pulling on a dressing-gown, she followed him up the three flights of stone stairs to his sanctum, a bewildering jungle of jars, batteries, wires, coils and mysterious instruments. "Listen, mother," he said, pressing a key on a table. From the far end of the half-lit room came the insistent buzzing of an electric bell. Not fully comprehending exactly what was happening, but sensing she had been called to see and hear an important success, she said: "It's wonderful." Which it was, for Guglielmo had set off his bell entirely by radiation from a distance of some 30 feet, where before a connecting wire was always necessary.

Yet even the young visionary was shrewd enough to realise that something more spectacular than this would be needed to win over Giuseppe—and his financial backing. So he managed to increase the range to other rooms in the house, to downstairs on the ground floor, and soon to nearby parts of the grounds. By the spring of 1895 the estate was dotted with wooden poles which served him as crude aerials. Before long Guglielmo was transmitting and receiving signals (usually the letter S in Morse) across distances of over a mile in the grounds, and Giuseppe was persuaded to witness at close quarters some of these tests, one of which achieved the success of receiving a signal from a spot out of sight over the brow of a hill. Before the year 1895 was out, Marconi, aided by the devoted Alfonso, was transmitting successfully over a range of some two miles. Alfonso would fire a hunting rifle into the air to tell his brother when contact was made over this astonishing distance. "But I knew my invention would have no importance unless it could make communication possible across natural obstacles like hills and mountains," he said long afterwards.

There remained the obstacle of Giuseppe Marconi. He was undoubtedly impressed by these achievements, and perhaps more than his son, he realised that the whole thing was still in its crudest infancy, a long way off from making any money on a commercial scale. He asked Guglielmo for evidence of real progress in sending messages, for before he would be prepared to invest precious lira in wireless, he wanted to be certain that a good return on his capital would be forthcoming. Nevertheless, he shot through Guglielmo's heart-felt disappointment with an unexpected shaft of warmth and generosity. "In the meantime, here is enough money for the things you need in your work," he said, handing his son 5,000 lira.

## Chapter 2

# SCIENTIST IN EARNEST

From that day on, life was never quite the same at the Villa Grifone. For Marconi, the encouragement formed a personal challenge that few outsiders would ever understand. It also meant scientific freedom for a while, and so he at once began what was to occupy him more on than off for the next thirty years or so, the struggle to perfect the basically crude and imperfect apparatus he used in order to achieve his major successes that were to prove to a doubting world that wireless would work. He began with his receiving apparatus, always the weakest link in the chain of simple radio transmission. For Annie, it was the vindication of her long years of hope and sympathy and encouragement. For Giuseppe, it was the last chance for Guglielmo to prove his real worth, to make a lot of money out of his invention and settle down on another fine estate as a landed Italian gentleman keen on science in an amateur sort of way. Perhaps he might even buy a property around Pontecchio!

The next move that was to be made by the Marconi family betrayed their rustic origins.

Here was young Guglielmo, signalling without wires over two miles of countryside, clearly on the threshold of something big (Alfonso called him a "wizard"), yet no one in the household quite knew what to do next. Peasants, even landed peasants, were not versed in matters of scientific progress. So they did what all Italian families do in like circumstances, they put all their heads together, and they consulted the family doctor and the priest. "Being a loyal Italian subject," Marconi explained, "I considered it my duty to inform my government of my invention." So between them, they composed a mighty letter to the Minister of Posts and Telegraphs in Rome. Then everybody sat back and waited.

At last an official reply came. The Italian Government was not interested. The country was in fact still suffering from political strife, and scientifically was somewhat behind other countries. The blow hit Guglielmo with bitter force, and it was very many years before he got over it, if indeed he ever did. Anyway, Annie was undaunted, and recognising England as the greatest maritime nation of the day, decided that her son must take his invention there. "Mind you," said Marconi, "Italy did not say the invention was worthless, but in those days wireless seemed to hold promise for the sea, so off to England I went." It is a striking thought that had the great letter from the Villa Grifone been directed to Italy's Minister for the Navy, the whole of that country's subsequent history might well have been different. At the time, the Marconis thought the only feasible application of wireless would be on ships, especially for ship-to-shore communication, and in fact, for some years afterwards, Guglielmo's prime aim was to benefit the world's sailors.

In any event, it was ostensibly to try and interest the British Government in the possibility of signalling by wireless waves between lighthouses and lightships and the shore that Guglielmo Marconi, aged nearly twenty-two and accompanied by his mother, arrived in England in February, 1896.

There was something at once touching and comic about the scene that was to mark for Marconi the beginning of his cosmopolitan career and a long exile from his native land. Guglielmo himself looked rather like a youthful Sherlock Holmes in his deer-stalker hat and long overcoat, a quiet dandy sure of nothing but the worth of his invention, its apparatus packed away for safety in his famous black metal box, and really rather apprehensive and naive. Annie, dressed more soberly in a dark suit and a hat tied on with a veil, kept a motherly eye on her offspring and on the heavy trunks and cases with which they had travelled. She was glad of the chance to see England and some of her relatives again, was far more resigned to the possibility of a long stay away from Italy which she foresaw would be necessary, and far less apprehensive than him of the final outcome. Even so, for a Victorian matron unaccompanied by her husband to descend on London in those days was an ordeal in itself, and she too was obviously more than a little naive about the whole adventure. Fortunately, fate stepped in kindly at once in the person of one of her cousins, Henry Jameson-Davis, a young man of the world then working as a milling engineer and later to become a sure help to Marconi in his early business ventures. He met the pair at Victoria Station and found them dazed, helpless and near to despair. His appearance could not have been more welcome.

At the Channel port the British customs officials had looked rather suspiciously on the strange pair of arrivals from far-off Bologna, and their suspicions were aroused even further when their luggage came to be examined. With the natural curiosity of their calling, they were especially interested in the mysterious locked black box, which Guglielmo insisted on handling and carrying himself. He was forced to open it and was innocently puzzled by the dark looks on the faces of the customs officers as they heartlessly drew out the conglomeration of wires and rods, jars and sheets of zinc, batteries and dials. Was the shy young foreigner in reality an anarchist or a spy, intent

A. CAMPBELL SWINTON,
ELECTRICAL ENGINEER.

Telegraphic Address
"DUNAMIS, LONDON."

TELEPHONE No 3166.

66, Victoria Street,
London, S.W.

March 30 th. 1896.

Dear Mr Preece,

I am taking the liberty of sending to you with this note a young Italian of the name of Marconi, who has come over to this country with the idea of getting taken up a new system of telegraphy without wires, at which he has been working. It appears to be based upon the use of Hertzian waves, and Oliver Lodge's coherer, but from what he tells me he appears to have got considerably beyond what I believe other people have done in this line.

It has occurred to me that you might possibly be kind enough to see him and hear what he has to say and I also think that what he has done will very likely be of interest to you.

Hoping that I am not troubling you too much.

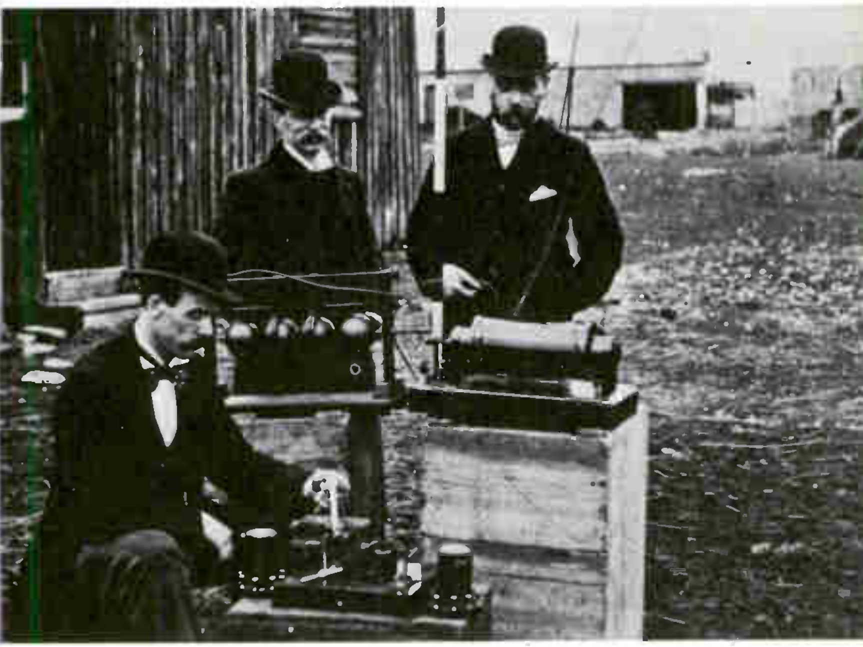
Believe me,

Yours very truly,

A. A. C. Swinton

W. H. Preece Esq. C.B.

Guglielmo Marconi
101 Hereford Rd
Bayswater Bologna



3-4 Marconi's letter of introduction from the electrical engineer Alan Swinton to William Preece of the General Post Office. Preece's warm support for Marconi's experiments really started him on his career. It was Preece's idea to try to bridge the Bristol Channel by wireless in 1897. His men are shown here examining the apparatus used in the successful experiment.

5-6 The wireless station at Poldhu, Cornwall in 1901 with its first aerial. From here the first wireless signals were transmitted across the Atlantic to Signal Hill in Newfoundland. A triumphant Marconi, with his helpers, Kemp (to his left) and Paget, is shown at Signal Hill after receiving the signals via an aerial flown precariously on a kite.

on destroying all that Victorian London held dear? In the event, the Marconis were finally allowed to proceed, but not before the entire valuable contents of the black box had been pulled to bits and damaged beyond repair.

Jameson-Davis soon fixed up his kinsfolk in suitable accommodation and they settled in happily in genteel lodgings at 71 Hereford Road, Bayswater, a far cry from the lofty rooms and noble vistas of the Villa Grifone. He then helped Guglielmo procure new apparatus, and when this was working, he recounted: "The possibilities of wireless telegraphy were very evident to me, and for some weeks experiments were conducted at my home; many prominent experts and others came to see them." Notable among the latter was a man called Alan Campbell Swinton, who had already done electrical research himself and who knew exactly whom Marconi must meet. So he gave Guglielmo a letter of introduction to Mr. (later Sir) William Preece, Chief of the Engineering Department of the General Post Office. Preece, of Welsh extraction, "a true Victorian gentleman," was a kindly, humane man who had made experiments as long before as 1885 with a view to improving the speed and efficiency with which warnings of impending storms could be signalled to lightships and lighthouses. In his letter to this august official, Swinton mentioned Marconi's "new system of telegraphy without wires, at which he has been working . . . it appears to be based upon the use of Hertzian waves, and Oliver Lodge's coherer, but from what he tells me he appears to have got considerably beyond what I believe other people have done in this line."

From the very first instant that Guglielmo appeared at the headquarters of the General Post Office in St. Martin's-Le-Grand with his equipment, Preece took to him, finding him "open and candid," and his claims certainly impressive. In his own quiet, convincing way, Marconi had described the magical effects his apparatus could produce, and how he had discovered that when his metal cylinders "were placed on top of a pole 2 metres high, signals could be obtained at 30 metres from the transmitter," and that "with the same cylinders on poles 4 metres high, signals were obtained at 100 metres, and with the same boxes at a height of 8 metres, other conditions being equal, Morse signals were easily obtained at 400 metres."

Fortunately for posterity, another keen-eyed and intelligent observer was present that day. He was P. R. Mullis, then a boy assistant in Preece's office, and the little account he wrote in 1940 has a charming vividness: "Mr. Probert (the electric light superintendent) brought into Mr. Preece's room a young foreigner who was introduced as Signor Guglielmo Marconi. He had with him two large bags. After mutual hand-shakings and while the Chief cleaned his gold-rimmed spectacles, the contents of these bags were placed on the table and seemed to consist of a number of brass knobs fitted to rods, a large spark coil and some odd terminals, but most fascinating of all a large-sized tubular bottle from which extended two rods. So far as could be seen, these terminated inside the bottle on two discs, very close together. Between them could be seen some bright filings or metal particles (the coherer/receiver). This immediately took the Chief's eye and was obviously, by the careful way it was handled, something of great importance and certainly of particular interest to Mr. Preece."

Young Mullis was not in on the technical talk that ensued, but later he remembered that "Mr. Preece pulled out his large gold hunter watch and said that 'It has gone twelve. Now take this young man over to the Refreshment Bar and see that he gets a good dinner to my account, and come back here by two o'clock.' I had got to like this quiet young foreigner with his quaint English and dextrous manner. We had a good dinner and over our basins of tea he told me of his native land. Then with plenty of time to spare we strolled up Farringdon Road where my new friend was very interested in the number of kerbside stalls with their accumulation of fruit, junk, and old books and things."

They arrived back at the office in good time, waiting outside until Preece returned: "The Chief came along and as we entered the room I noticed that everything was just as left with the exception of a piece of paper which had been placed under the contact of the telegraph key. This was removed and after one or two preliminary adjustments to the connections and brass balls by Mr. Marconi, the key was depressed and immediately the bell on the adjacent tube commenced and continued to ring. Mr. Marconi then went over to the glass tube, and gave this a few sharp taps and the bell ceased ringing. I knew by the Chief's quiet manner and smile that something unusual had been effected. The following day and the rest of the week experiments were run off." Then like a true chronicler, Mullis focuses the scene for us in time: "At the end of each day, Preece went home to Wimbledon in his brougham," probably dropping Marconi off in Bayswater en route. Preece gave Guglielmo every assistance, allowing him to use his own technical laboratory and standing by him loyally in the trials that lay ahead. In many of these early experiments Mullis acted as Marconi's eager assistant, captivated by the young Italian's characteristic courtesy and his way of saying: "We will do this, or that," never "I will do this, or that."

Each evening in the dim Bayswater sitting-room the crude Marconi transmitter was given further private tests and all the talk was of the exciting possibilities that lay ahead now Preece had been won over and was arranging long-range demonstrations before other G.P.O. officials. The first of these was a modest one: to throw wireless signals from the roof of the St. Martin's-Le-Grand building to the Savings Bank Department nearby, a mere 300 yards.

Yet once again the pattern of Guglielmo Marconi's life unfolded another significant step. For among the bystanders on the pavement watching the inventor as he rigged up his equipment on the G.P.O. roof was an alert, ginger-haired man who swiftly caught Marconi's eye and shouted up: "What are you doing up there?" "Come on up and I'll show you," Marconi shouted back. The man appeared on the roof-top with such alacrity that Marconi was convinced he must have shinned up the drain-pipe. He was George Stevens Kemp, then an ex-petty officer of the Royal Navy, of their kind the salt of the earth, and he was working for Preece as an assistant. But for no longer, for from that day on he worked for Marconi, linked by a close bond of loyalty, affection and respect that was always mutual.

As Orrin E. Dunlap says in his book *Marconi: the Man and his Wireless*, one of Marconi's early associates told him: "It was natural that an inventor of his personality and ability should attract the cream of the engineering crop. He had a fine collection of experts. George S. Kemp, an ex-Navy man, was his first assistant and remained with him until his death in 1933 . . ." Like all those who inspire such abiding loyalty, he did not spare his co-workers, however, and expected them to labour as hard as he did himself. This associate continued: "I have seen him work thirty hours at a stretch. He hates routine business, and while he has a business sense he lacks administrative and organizing ability. He is no mixer; out of 700 on the Marconi staff probably not more than half-a-dozen know him well enough to speak to him." Tested by adversity and disappointments, he never lost confidence in his mission and expected no one else to give up hope either. Always his working slogan was "*Occorre progredire!*"—"We must progress!" As Dunlap says: "Sceptics could not dent the armour of his faith."

So it was in those first hectic years of tests and demonstrations in Britain. The London demonstrations were such a success that Preece arranged the next to cover much greater distances over Salisbury Plain, not far from Stonehenge. It was now September, 1896, and on Three Mile Hill, before Army, Navy and Post Office experts, Guglielmo mounted his aerial wires 25 ft. and 10 ft. from the ground, some of them 90 ft. long, and achieved good results over a distance of 1¾ miles.

By now, the Marconi tests were becoming talked of in scientific circles, but if Preece and one or two others were convinced supporters, orthodox scientists were many of them less than enthusiastic. The great Lord Kelvin, for instance, well aware of what he termed the "ether-waves" and usually wise as well as kindly, is said to have sneered: "Wireless is all very well, but I'd rather send a message by a boy on a pony." There were other doubters and sneerers, too. In later years, when world success was his, Guglielmo was to answer them, quietly but effectively: "By the time I was twenty I was fairly well acquainted with the published results of the work of the most distinguished scientists who had occupied themselves with the subject of electric waves; men such as Hertz, Branly, Lodge, Righi, and many others. With regard to Professor Righi, much criticism was levelled at me in the early days because in my first experiments I used a form of oscillator which had been devised by him and which itself was a modification of Hertz's oscillator. By availing myself of previous knowledge and working out theories already formulated I did nothing but follow in the footsteps of Howe (inventor of the sewing-machine), Watt, Edison, Stephenson and many other illustrious inventors. I doubt very much whether there has ever been a case of a useful invention in which all the theory, all the practical applications and all the apparatus were the work of one man."

However, it fell to Preece to defend him at the time. Lecturing in London on "Telegraphing Without Wires" as early as December, 1896, he expressed his complete faith in Marconi's work and revealed that the G.P.O. had authorised him to spare no expense in staging the young inventor's demonstrations. Again, in June, 1897, lecturing to the Royal Institution, he declared: "It has been said that Mr. Marconi has done nothing. He has not discovered any new rays; his transmitter is comparatively old; his receiver is based on Branly's coherer. Columbus did not invent the egg but he showed how to make it stand on its end, and Marconi has produced, from known means, a new electric eye more delicate than any known electrical instrument and a new system of telegraphy that will reach places hitherto inaccessible."

Before the year 1897 was out, another major step forward was achieved. "GUGLIELMO MARCONI, of 71 Hereford Road, Bayswater," was on 2nd July granted British Patent No. 12,039 for an invention by which "electrical actions or manifestations are transmitted through the air, earth or water by means of electric oscillations of high frequency." "Then," said Marconi himself later, "having established my priority in this new system of communication, my next thought was how to launch my invention." He had not long to wait. Alongside Preece's calm support came many offers of financial reward, some firm, others ludicrous. One of the most tempting was from a Milan bank offering 300,000 lira for the rights in this invention. When old Giuseppe got to hear about this he was proudly excited, and immediately advised his son to buy up the neighbouring property at Pontecchio, the Villa Banzi and settle down as an Italian country gentleman, complete with lands and livestock. But as Guglielmo told a friend after the success of the Salisbury Plain tests, "*La calma della mia vita ebbe allora fine*"—"The calm of my life ended then." Perhaps he never wanted to be a country squire; certainly at this time he knew there was still a great deal of work to be done and he must be the man to do it. So he refused.

In private, he was studying theoretical physics every evening, trying to fill the many gaps in his scientific education, and reading everything that was being published on electricity in Europe and America. In public, he was staging ever bigger and better demonstrations, not merely over land but over water, now. After stepping up his range of transmission on Salisbury Plain to over 4½ miles, Marconi, at Preece's suggestion, bridged by wireless the 8½ miles between Lavernock Point, near Penarth, in South Wales and Flat Holm Island and Brean Down, Somerset. On several occasions in

May 1897 Preece enthusiastically reported: "Excellent signals have been transmitted . . . and we have by no means reached the limit." Some of this success was achieved by the use of kites to suspend the aerial wires, which were now longer than ever before.

Invited by Preece to watch these tests was Professor Adolphus Slaby, a German electrical scientist who had been working on Hertzian waves and had himself transmitted them successfully. Describing how the first contact was established between South Wales and Somerset, he said: "It will be for me an ineffaceable recollection. Five of us stood around the apparatus in a wooden shed as a shelter from the gale, with eyes and ears directed towards the instruments with an attention which was almost painful. The hoisting of the flag was the signal that all was ready. Instantaneously we heard the first *tic-tac*, *tic-tac*, and saw the Morse instruments print the signals which came to us silently and invisibly from the island rock (Flat Holm), whose contour was scarcely visible to the naked eye—came to us dancing on that unknown and mysterious agent, the ether. I have seen 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 meaning of his success." Not long afterwards, however, there was to be bitter rivalry between Marconi and the Germans, who granted Slaby fresh patents for an aerial system slightly modified from the Italian system.

On July 20th, 1897, with capital of £100,000 put up by Jameson-Davis and some of his business associates and other friends and members of the family, Marconi registered his first private company, The Wireless Telegraph and Signal Co. Ltd. Jameson-Davis was the first Managing Director, and Guglielmo took £60,000 worth of stock as part payment for the use of his patent, which he returned to the firm as capital, and received an immediate payment of £15,000 in what he called "resounding sterling." Up to this point, at any rate, the one most concerned that the real value of the invention should be exploited fully in the Marconi interests only was Giuseppe, and soon, on his insistence, the name of the company was changed to Marconi's Wireless Telegraph Co. Ltd. Later it was to become simply The Marconi Company, Ltd., which still exists with many subsidiaries as a world organisation concerned with radio- and tele-communications. He would have liked this name even better, had he lived to see it.

Guglielmo did not change his mode of living at this point, as might have been expected. He continued to live modestly in Bayswater, although Annie spent some time each year back in Italy with her husband. Alfonso came over as his brother's assistant, working on "a pitiful expense account" without complaint, still fired as he was with fanatical enthusiasm for the inventor in the family. The inventor himself, however, was changing a lot now. In great demand as a public lecturer and professional wireless consultant, he was now in the commanding position of being able to refuse both sorts of invitation whenever he wanted to, preferring to organise his own extending experiments in his own way, all of them with the devoted Kemp. More significantly, he was changing as a man.

He ceased swiftly to be the wide-eyed innocent in an alien land, full of wonder and apprehension. Writing about this period in later life, he revealed that "The English believed at the start that they had to do with a young man of scant experience who could easily be dominated," recounting the fact in a way that implied he at least always knew they were wrong. In his spidery letters to England from Pontecchio, old Giuseppe contined to fuss and worry that his "head-in-the-clouds" son might not be getting the best terms from the sordid but hardheaded world of commerce. Giuseppe need not have bothered: Guglielmo was his own son, as tough a business negotiator as one would ever encounter. He certainly did not intend to join the pathetic list of able inventors (whose lives he had studied) who made nothing out of their discoveries. The young man of twenty-three became almost suddenly canny, not a little hard, not a little prickly, commercially-minded to the hilt, determined to dominate and feeling already in full measure the need to have round him a group of willing acolytes whom he could in fact dominate and master, yet at the same time on whom he could rely completely. He began to love competence for its own sake.

He still never cured his innate shyness, and began to show even more than before his basically mercurial temperament. To some few people, "Mr. Marconi" (it was always thus) was a scientific wizard, brilliant yet totally without pretentiousness or "side", marvellous with his hands, endless in his patience. They knew the best in him. To others, he seemed but an effete, aloof dandy, a mysterious foreigner. They never penetrated the external appearance. To very many more people he seemed a dull chap, or as one famous Edwardian society hostess in London remarked when he steadfastly resisted being drawn into her "circle": "A most odd and extraordinary young man." They merely expected him to conform, which is the last thing that must be expected of genius. To big business and governments he seemed a prickly young fellow who was proving a surprisingly hard nut to crack. They met the true measure of the man. To a few people, he was completely selfish, immune to the feelings and wishes of others, absorbed beyond comprehension in his own destiny and his own work. They penetrated one crack in the Marconi facade, and did not like what they saw.

Lastly, to quite a number of women, he proved lively and magnetic, even irresistible, and for the first time in his life Guglielmo began to realise that he was, by nature, quite incurably susceptible to their charms—and wiles. His daughter, Degna, feels that the paradoxes in his nature had a certain logic of their own. "He was vain in that he accepted his genius," she says, "but not conceited. He was jealous, but envied no one. His delight in tearing down the accepted theories of physicists was impish. He was audacious, it took audacity to propose throwing an arc of waves from here to heaven knew where, but he backed his boldness with precision." She also believes his life was something of a conflict between Marconi the entrepreneur and Marconi the scientist. This was a conflict that was inevitably to grow with the years, but at this time it did not trouble him much, since he thoroughly enjoyed both roles, and saw at once that he must make money to enable his work to continue and develop. His self-assurance now grew to the point where he could play both roles simultaneously and yet fully. He needed independence above all, and it is not generally known that in September, 1897, when some slight difficulty arose with the continuation of experiments sponsored by the British Post Office, he wrote to Preece: "If, as I fear, the department does not intend continuing in the friendly bona fide relation as you and I believed it would, I shall be obliged . . . to proceed to Russia, Austria and other countries which are very anxious to have extensive experiments carried out at their expense." This was not a threat to an old friend and supporter, for, as he added with truth, his feelings towards Preece "are always the same." But it was further proof of the young man's determination not to be baulked by officialdom in any country, of his desire to find scientific freedom wherever it was offered. It makes interesting speculation, now, to imagine what the results to human history might have been had he gone to work for one or other of these European powers, instead of confining his genius largely to Britain and America as in fact he did.

Meanwhile, there were other matters to attend to. He was now due to be called up for military service as an Italian subject. Thanks, however, to representations made by Lord Kelvin and General Ferrero, the Italian Ambassador in London, Guglielmo was spared the agony of what to him would have been a desperate decision—to follow his intense patriotism and waste three vital years in uniform, or to stifle that sentiment and take out British citizenship, as the Jamesons urged. In the event, as a keen amateur sailor, and the erstwhile owner of a boat moored in Leghorn Harbour, he was assigned as a naval cadet "in training" to the Embassy, and given full pay and allowances for non-existent duties, so that he could continue his work as before. The money he sent anonymously each month to the Italian Hospital in Bloomsbury.

Italy now began to take an interest in him, in fact, not as a pseudo-cadet (who once was refused entry to the Leghorn Naval Academy), but as the inventor of a potentially valuable marine signalling device. Marconi had deliberately reserved the Italian rights in his patent, and that summer he was ordered back to his native country to give official demonstrations there. Italy welcomed him as a famous and honoured subject, and the Italian Navy gave him every facility for the much-publicised tests—in ironic contrast to the events of a year or so earlier. At the San Bartholomeo shipyard at Spezia in June came the first recorded ship-to-shore wireless telegraphy, when communication was made with the ironclad *San Martino* at distances of up to twelve miles. Making good use for the first time of the tall masts of a ship, Guglielmo used transmitting aerials some 115 ft. high, with slightly higher ones on shore.

Although the results were successful enough to persuade the Italian Navy to become the world's first to use radio, the Italian excursion was not an unmitigated triumph for Marconi, as he would have wished. The Spezia tests were marred by bad weather and constant atmospherics, and although there was a royal reception at the Quirinal Palace in Rome at which King Umberto and Queen Margherita showed him every kindness and great interest in his work, and many other dinners, banquets and receptions at which "many complimentary speeches were made with reference to my invention," there were ominous rumblings in London. Marconi's absence from England had led to unfounded suspicions about his intentions, and some of the company's original subscribers were threatening to withdraw their money unless the matter was settled satisfactorily. However, all was smoothed over by Jameson-Davis, and Guglielmo was back at work again in England by the late summer. Giuseppe and Annie were rightly proud of their now famous son's reception in his native land, and when the wily old father wrote to him: "Do not pay attention when people try to hurry you, saying that supporters and investors will get tired of waiting; these are only artifices to make you accept what is in their interest, rather than yours," he knew what he was talking about.

## Chapter 3

# RADIO WORK

Marconi's first task late in 1897 was to set up the first permanent wireless station, and this he did at The Needles Hotel, Isle of Wight, close to the famous tall rocks called The Needles at the western end of the island. A 115 ft. mast was erected in the grounds, overlooking Alum Bay, and good radio contacts were made between the shore station and the small steamers *Solent* and *Mayflower* hired from the old London and South Western Railway at Southampton. These two craft ploughed back and forth in foul weather in Alum Bay, the Solent, Poole Bay and off Bournemouth and Swanage, picking up the Morse clicks that Marconi was sending out from the Isle of Wight. A range of some eighteen miles was achieved, but more important than that, the waves had penetrated some really terrible weather at sea and, over a short distance at least, had not been limited by the curvature of the earth.

These were the two main headaches Marconi was to face during the next few years—years which for him were full of intensely absorbing, often hazardous and disappointing work. All the time he was filled, as he was to be for several years yet, by an enormous love for the sea and the men who daily risked their lives on it. At this stage he can have had little clear inkling of the vast possibilities of radio broadcasting as such; but if he could save even a few lives, a few valuable cargoes, from the insatiable sea, then he knew he would not have laboured needlessly. Although later he was to do a great deal of his developing radio work actually at sea himself, at this stage Guglielmo was to spend most of his time on bleak coasts, wind-swept cliffs and lonely shores, lashed by gales and spray with often only a tiny hut or shack for shelter, watching his ever-loftier masts tremble in the face of sea-tempests, listening patiently for the faint Morse signals coming in over the coherer. It was a milieu he loved to the innermost core of his being.

With the formation of the company the official support of the British Post Office could no longer be given to his work, and so, truly from now on, Marconi was alone. His affection for Preece remained unchanged, however. That lovable civil servant was now trying to establish his own radio link between Dover and Boulogne, but although he was exclusively using Marconi apparatus, he lacked the Marconi touch, and his efforts were not successful.

In February, 1898, another shore station was set up with another big mast in the grounds of

The Madeira Hotel on the mainland at Bournemouth, about fourteen and one-half miles from The Needles Hotel. Radio contact was swiftly established, and thus was started the first true permanent radio link, since messages clicked back and forth for some four years. Many famous V.I.P.'s went to one end of the link or the other to witness the new marvel, among them Lord Tennyson, the poet, Lord Charles Beresford, and the once-sceptical Lord Kelvin, who now insisted on paying the usual charge of a shilling for the telegram he sent from Alum Bay to Bournemouth. His telegram must therefore go down in history as the world's first paid wireless message, and governments everywhere were duly impressed, as Kelvin hoped they would be. However, government reaction to his efforts so often proved troublesome to Guglielmo Marconi, and this occasion was no exception. The claim of Kelvin's telegram, it seems, "sailed a little close to the bleak wind of disapproval with which the Postmaster General might have defended his monopoly rights over inland communications." Fortunately, one of the messages sent that day was to the always diplomatic Preece. Later in 1898, Marconi proved typically prickly over certain charges insisted on by the manager of The Madeira Hotel for the use of his front garden for the wireless mast, and so everything was moved from Bournemouth and re-erected at

The Haven Hotel at Sandbanks, a desolate, barren beach about six miles from Poole. The Needles-Sandbanks link was then completed with ease at an increased range of eighteen and one-half miles, and the Poole station, as it was usually called, became the inventor's first major field experimental centre. It was to continue operating until 1926, and Marconi often stayed there for long periods at a time, so often, in fact, that Annie Marconi, tired of being left alone in London, would come down to Dorset to join him.

The year 1898 saw Marconi busily setting up a variety of wireless links and naturally creating great public interest. He and Kemp managed to set up radio communication between the Smoking Room of the House of Commons in London and the treasurer's office at the famous St. Thomas's Hospital across the River Thames. Mr. Speaker himself sent and received a message before an august company of Cabinet Ministers, M.P.s and other official big-wigs. From July to September a more significant link-up was maintained, this time between Rathlin Island, off the north coast of Ireland, and Ballycastle, Co. Antrim, on the mainland.

This was established by Kemp and another man, without Guglielmo's direct participation, and was the result of a direct request to the new company from none other than Lloyd's of London. As Kemp wrote in his diary at the time: "Lloyd's complained of not being able to report steamers from Torr Head on the north-east corner of Ireland in spite of these steamers being able to report to the lighthouse on Rathlin Island. They requested me to fit a wireless station at Rathlin Lighthouse and another at Ballycastle," which he did so successfully that on the very next day he was able to report to Lloyd's the progress of ten ships in dense fog, over a distance of seven miles. In itself this feat was just one small one in a time of many others, but it achieved a far greater purpose. Surveying the whole history of wireless at sea some forty years later, the shipping journal *Fairplay*, recalling the Rathlin-Ballycastle link, wrote: "Now that long-distance wireless is common, it is just as well to recollect that in 1898 experimental stations over a distance of seven miles were considered adequate.

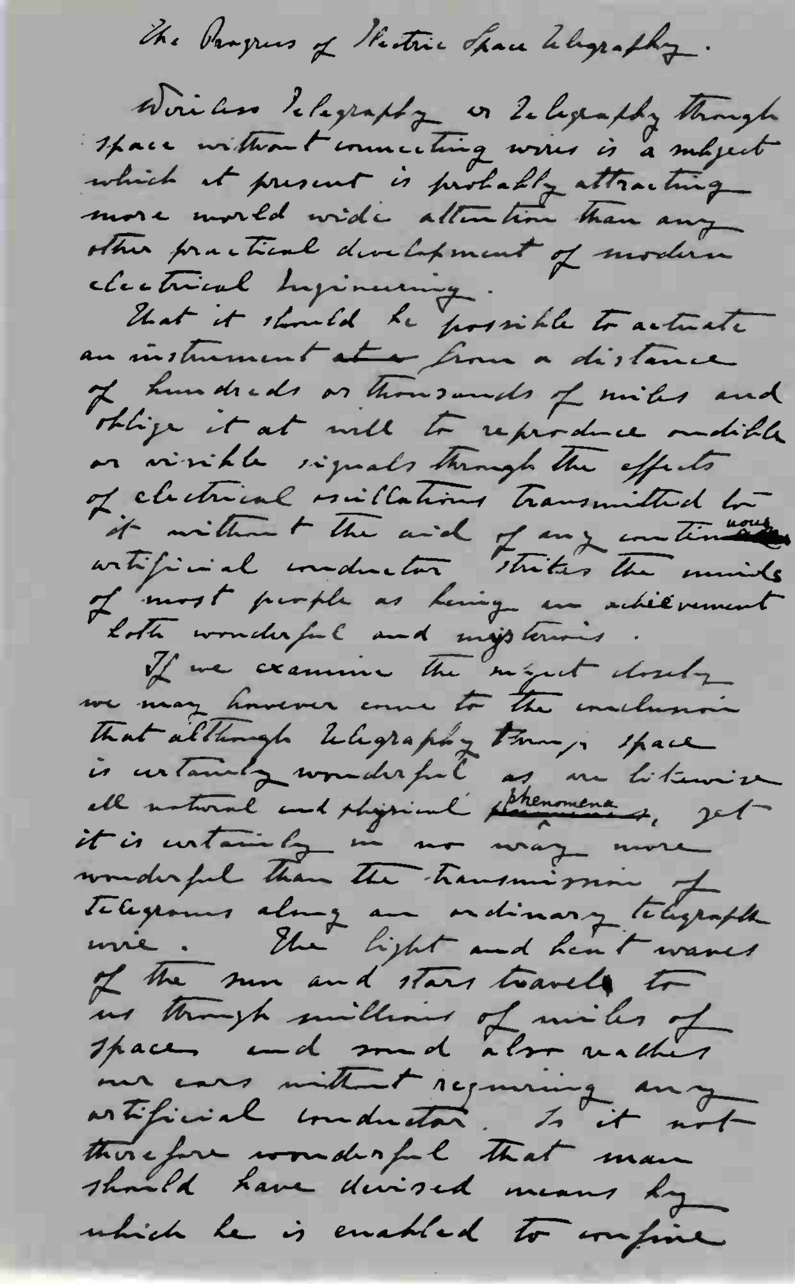
"The results of the experiments, however, satisfied the committee of Lloyd's that there was something in wireless, and shortly thereafter all Lloyd's main signal stations on the coast were equipped to send and receive wireless, and signalmen were specially trained for this purpose. With stations so equipped, it was quite usual to have positions wirelessed and then sent on to Lloyd's . . . Later on, Lloyd's equipped their main signal stations abroad, but in 1909 the Government took over the control of all wireless stations on the British coasts, and later all the various governments abroad took control of the wireless at Lloyd's signal stations. In those times Morse was used for signalling, and it is a relic of that period that we have the present S.O.S. This signal was adopted as the easiest and clearest message by Morse to be repeated over and over again."

This particular wireless demonstration was to result all too swiftly in tragedy, yet even that was to further radio progress. Kemp's assistant, Glanville, lost his foothold on the cliff-top on Rathlin Island whilst collecting geological specimens on a foggy day, and fell to his death. This led Marconi to close his stations in Ireland and bring his staff home, but the value of the link had been so clear that the lighthouse-keepers and others learnt how to operate wireless apparatus themselves. With the growing awareness of the value of wireless came the realisation that Marconi's men could not be expected to do all the work themselves, and soon that most honourable of callings, the wireless operator, was born.

It is difficult for us today to realise just how primitive even these quite considerable radio achievements really were. Not only was Marconi's equipment incredibly makeshift and Heath-Robinsonish, it lacked real power to carry messages more than a comparatively few miles. Everything was still in faint Morse, and everything was still hopelessly at the mercy of atmospherics in bad weather. Two transmitters operating near one another tended to blot each other out, making reception impossible. Wave-lengths allocated for special stations were hardly known, and everything was transmitted on equal power, so that anyone with an electrical bent who knew how to build a simple receiver could eavesdrop on nearby messages to his heart's content. These and many other technical difficulties were to engage Marconi's concentrated attention in the years to come, and every one was to be solved in its turn.

Meanwhile, in the summer of 1898 came a demonstration that, perhaps more than all the earlier ones, was to make the biggest impact on the ordinary man in the street, and probably on nontechnical commercial enterprises as well. In spite of Glanville's death, it too was to take place in Ireland, to Annie's great delight, and largely because of the enthusiasm of a man called John Joseph Fahie (who seems to have coined the term *broadcast* for wireless messages sent out in this same year). Anyway, it was Fahie who pointed out that radio would be very useful in reporting speedily on sporting events, and the tip was taken in practical fashion by the Dublin *Daily Express*. This newspaper therefore asked Marconi to cover the Kingstown Regatta yacht races in July. Guglielmo accepted with glee. He chartered a fast steam tug, the *Flying Huntress*, fitted its


7-8 The map shows the dates and stages when signals from Poldhu were received by Marconi on board S. S. *Philadelphia* in 1902. This experiment confirmed the possibility of a transatlantic linkup and encouraged Marconi to set up more wireless stations. He is shown at wintry Glace Bay in Canada in 1902 with his companions.



The Progress of Electric Space Telegraphy.

Wireless Telegraphy or Telegraphy through space without connecting wires is a subject which at present is probably attracting more world wide attention than any other practical development of modern electrical Engineering.

That it should be possible to actuate an instrument from a distance of hundreds or thousands of miles and oblige it at will to reproduce audible or visible signals through the effects of electrical oscillations transmitted to it without the aid of any continuous artificial conductor strikes the minds of most people as being an achievement both wonderful and mysterious.

If we examine the subject closely we may however come to the conclusion that although Telegraphy through space is certainly wonderful as are likewise all natural and physical phenomena, yet it is certainly in no way more wonderful than the transmission of telegrams along an ordinary telegraph wire. The light and heat waves of the sun and stars travel to us through millions of miles of space and sound also reaches our ears without requiring any artificial conductor. Is it not therefore wonderful that man should have devised means by which he is enabled to confine

9 Handwritten draft of a lecture given by Marconi on "Wireless telegraphy." One of the most single-minded of men, Marconi was tireless in promoting and developing his great invention.

mast with a 65 ft. aerial, installed another mast nearly twice that height by the harbourmaster's house at Kingstown and at once began to send and receive the world's first wireless messages at sea not concerned with safety.

Over 700 brief messages were relayed from the tug to Kemp's Morse inker, from which he transcribed them and telephoned them to the newspaper office in Dublin, five miles away. As the yachts sped and turned, Marconi enjoyed himself enormously, becoming the first radio sports commentator with his terse but nautically accurate reports: *The "Rainbow" having crossed the line before the gun was fired, was recalled, thereby losing three-and-a-quarter minutes; the "Alisa" stayed, and went away on the port tack, as did also the "Astrid". After going a short distance, the "Bona" also stayed, following the example of the other two, the "Rainbow" and the "Isolde" standing in under Howth.* The paper was thus able to print reports on the races as they took place and while the yachts were far beyond telescope range on the shore. The "substantial payment" the company received for their services, the enormous publicity and the light relief it gave personally were all useful in their different ways. Guglielmo said afterwards of this completely successful venture: "It opened the eyes of a great many people to the commercial possibilities of wireless. Previously it had been the more scientifically-minded who were interested. Now, the man in the street began to wonder whether this wireless might not be of use to him." The Kingstown relays also paved the way for another completely new profession, the radio commentator, sports or otherwise. The distinguished and much-loved line of Ed Murrow, Richard Dimbleby and countless others began with Marconi himself on those far-off breezy summer days of 1898.

There was more striking publicity—and more light relief—to follow. As it happened, the Prince of Wales (later King Edward VII), then fifty-seven years old, had lately fallen down a staircase at a Paris ball and injured his knee. He was recuperating on board the royal yacht *Osborne*, moored off the Isle of Wight for the 1898 Cowes Regatta, and to escape the cloying concern of his over-solicitous mother, then nearly eighty, he ordered the yacht to cruise around and moor out of the direct line of sight from her favourite residence at Osborne House nearby. One of the least expected readers of the accounts of the Kingstown transmissions was in fact Queen Victoria herself, and she swiftly saw that here was the chance to outwit her son and establish constant communication with the "invalid." So she summoned Marconi and ordered him to erect his wireless apparatus in the grounds of Osborne House and on the yacht. Always keen to create a good impression with royalty, Guglielmo admitted later that he accepted the order "with true pleasure," but chiefly for the reason that "it offered me the opportunity to study and meditate upon new and interesting elements concerning the influence of hills on wireless communications."

In any event, an 83 ft. tall aerial was erected on the *Osborne*, its lead-in wire running down into the salon, a corner of which served as a radio cabin, while a 100 ft. aerial mast was erected at Ladywood Cottage, set amidst the steep Wight hills, for the receiving end. Whilst Marconi was busy fixing up the shore apparatus one day, unaware of the old lady's odd ways and her fierce desire for seclusion, he was stopped by one of the Osborne gardeners, and the following amusing dialogue, or something very similar, ensued during the course of that day:

GARDENER: "Excuse me, sir, but will you go back and round, as Her Majesty is out walking in her Bath-chair."

MARCONI: "I do not wish to be interrupted in my work, and I shall go through the garden or leave."

QUEEN VICTORIA (having received the gardener's message): "Get another electrician"!

A COURTIER: "Alas, Your Majesty, England has no Marconi."

Later, when the Queen passed by in the garden, Marconi greeted her politely, removing his hat, but she completely ignored the liberty she considered he had taken, and so thoroughly offended him. He returned to his hotel under a threat of leaving immediately, but for once, Victoria had met her match and she knew it. She sent a carriage to fetch him and gave him a proper audience in Osborne House, wishing him every success and offering her congratulations on what she had now discovered were real achievements.

That August over 150 wireless messages were transmitted from the Royal Yacht to the shore, bearing day-by-day news of the princely patient from his doctor, all of which were passed to the old Queen. Some were quite lengthy, but most were brief if hardly earth-shattering: *H.R.H. The Prince of Wales has passed another excellent night, and the knee is in good condition: H.R.H. The Prince of Wales has passed another excellent night, and is in very good spirits and health. The knee is most satisfactory.* Everyone was very pleased with this demonstration, except perhaps the future King Edward VII, who was hoping for a week or two out of contact with his eccentric mother!

Early in 1899 came an event that rammed home the value of wireless in people's minds and which was far closer to the inventor's heart: Marconi's equipment was first used to save lives. The East Goodwin Lightship, in the

English Channel, was already equipped with radio, linking it with the South Foreland Lighthouse, twelve miles away. The crew of the lightship had already used their apparatus to good effect in January, when the German ship *Elbe* went ashore on the treacherous Goodwin Sands and they summoned the Ramsgate lifeboat to her aid, thereby saving over £52,000 worth of property. As a contemporary observer at the South Foreland station wrote: "A touch of a key on board the lightship suffices to ring an electric bell in the room at the South Foreland, twelve miles away, with the same ease and certainty with which one can summon the servant to one's bedroom at an hotel. An attendant now sleeps hard by the instrument at South Foreland. If at any moment he is awakened by a bell rung from the lightship, he is able to ring up in turn the Ramsgate lifeboat, and, if need be, direct it to the spot where its services are required within a few seconds of the call for help." On March 3rd, that key was pressed on board the lightship in deadly earnest, for that vessel herself had been run down by the steamer *R.F. Matthews*. The call was picked up at the South Foreland end by one of Marconi's growing band of assistants, Bullock, whose swiftness in calling out the Ramsgate lifeboat yet again undoubtedly saved the lives of the men on the lightship.

Wireless at this time was now capturing popular fancy a great deal. It seemed so mysterious, and yet so simple. With just a short-lived electric spark jumping across the inch gap between the two metal balls surmounting the induction coil of the transmitter to represent a Morse dot, and a longer stream of sparks to represent the dash, the long black-handled signal key seemed a simple enough device to operate. Yet it could "talk" to men sixty, seventy or more miles away, men separated by rain and fog, hill and cliff, river or sea. "Flinging words across a waste of sea" was a magical art in 1899, however commonplace it is today.

Guglielmo spent a lot of time now at the Poole station. He was worried a great deal about the curvature of the earth intercepting his signals over really long distances, and at this point he still believed this difficulty could only be overcome by having ever higher aerial wires. So long as the masts rose high enough, he believed (quite wrongly, as it proved) the distance of transmission would increase, even to thousands of miles. "What are a few thousand miles to this wonderful ether, which brings us our light every day from the sun for millions of miles?"

The press were beginning to take his work very seriously, and one of his most interesting interviews at this period he gave to Cleveland Moffett, correspondent of the American *McClure's Magazine*, and published in the June, 1899 issue. It shows very vividly Marconi's clear vision even at this early date and age (he was just twenty-five). Moffett found him with his assistants at Poole, busy yet very ready to talk. He asked him if there was likely to be any limit for undirected wireless waves: "Practically, none. We can do a hundred miles already. That only requires a couple of high church steeples or office buildings. New York and Philadelphia with their skyscrapers might talk to each other through the ether whenever they wish to try it. And that is only a beginning. My system allows messages to be sent from one moving train to another moving train or to a fixed point alongside the tracks; to be sent from one moving vessel to another vessel or to the shore, and from lighthouses or signal stations to vessels in fog or distress. Imagine a lighthouse or danger spot in the sea fitted with a transmitter and parabolic reflector, the whole kept turning on an axis and constantly broadcasting impulses in the ether—a series of danger signals. It is evident that any vessel equipped with a receiver could get warning, perhaps by the automatic ringing of a bell, long before her lookout could see a light or hear a foghorn. Furthermore, as each receiver gives warning only when its rotating reflector is in one particular position — that is, facing the transmitter—it is evident that the precise location of the alarm station would at once become known to the mariner. In other words, the vessel would immediately get her bearing, which is no small matter in storm or fog." This strikingly foreshadows marine radar and direction-finding, now universal, and demonstrates how far ahead Marconi's mind was already working.

He had further highly prophetic thoughts about a use of wireless then scarcely dreamed of by others. "In what direction do you expect your invention to be first utilised?" he was asked. Marconi replied: "The first may be for military purposes, in place of the field telegraph system. There is no reason why the commander of an army should not be able to communicate easily with his subordinate officers without wires up to twenty miles. It would be equally useful for the admiral of a fleet. I believe one of the greatest uses to which these instruments will be put, will be signalling in wartime." Military or naval units could always protect themselves by signalling in code, as indeed could the public. One day laws might be passed to protect the contents of a commercial or even a private communication. On the other hand, it was obvious that a distress signal from a ship should be picked up by the greatest number of reciving stations possible.

Even Marconi himself can scarcely have

realised at this time that two major wars and dozens of lesser ones were to be completely transformed by the widespread use of wireless: fighting forces without radio today—let alone a war undertaken with its aid—are so unthinkable that it is hard to believe that the inventor was speaking on the very threshold of the twentieth century. Wireless was creating a terrific impression everywhere, although only one man, the man responsible above all others, had any true vision of its future, as this interview showed. On the other hand, sceptics were still numerous, and there was much talk of wireless being but a "toy," a fascinating toy, perhaps, but still only a toy. A professor at Clark University, U.S.A., wrote to the magazine's publisher, S.S. McClure, to urge him not to give space to such absurdities as wireless, for this made the normally serious periodical quite ridiculous.

After this public glimpse of the Marconi vision, his next step now seems to have the ordinariness of the inevitable, although at the time it too created a great stir. Succeeding where Preece without his aid had failed, he bridged the English Channel by radio on March 27th, 1899. The French agreed to let him establish a small station at Wimereux, a coastal village, three miles from Boulogne, the scene of Giuseppe and Annie's wedding thirty-five years before. Many French Government officials watched both the preparations and the actual transmission to the English station at the South Foreland, thirty-two miles across the water, with the greatest possible interest. They were rather taken aback, however, to find the great Italian had only three helpers and was more than willing to shoulder his share of the labour involved, be it as an "engineer, a mechanic, an electrician, a builder's labourer, or anything else that the moment demanded."

At five o'clock in the afternoon on that historic Monday, Marconi played his inimitable part in the Entente Cordiale by pressing the sending-key on the French side, releasing the magic flashing sparks that sent "a great number of messages in French and English" back and forth. Guglielmo was his own operator on this occasion, and after sending the first message he swiftly transmitted the agreed signing-off signal: *VVV*, and switched off the transmitter. If any sceptics were present in the room, they did not have long to wait for their conversion. There was complete silence for a brief moment, then the receiver clicked and immediately began to ink out the incoming dots and dashes on its paper tape: *V* (the opening call-sign). *M* (Your message perfect). Guglielmo, the very first radio "ham," replied enthusiastically at once: *Same here. Two cms. VVV*. (Two cms. (centimetres) was the length of the transmitting spark used.). Again, if all unknowingly, Marconi foreshadowed the long years to come when a radioed *V* or *Vs* meant *V* for "Victory" to countless millions of oppressed people in Europe. It was certainly a striking victory here and now. The French had called for proof, and here it was.

Diplomatic as always, Marconi included in his later messages that day this one: *Marconi sends M. Branly his respectful compliments across the Channel this fine achievement being partly due to the remarkable researches of M. Branly*, for it was indeed Branly's filings coherer that was picking up these signals at each end. He also sent a message to his friend and future colleague, Professor J.A. Fleming that was received and read out at a meeting of the British Association, causing a deep and lasting impression. No wonder Kemp wrote in his diary that night: "This was a great day in the development of wireless telegraphy." The mood of boyish keenness for fun with waves continued a couple of days later when McClure visited the South Foreland station and to test the accuracy of the Marconi apparatus, Cleveland Moffett signalled from Wimereux, via the solemnly conscientious Kemp: *McClure, Dover: Gniteerg Morf Ecnarf ot Dnalgne Hguorht eht Rehte—Moffett* (Each word of the message being spelled backward). Soon the reply came through: *Moffett, Bou-*

*logne: Your message received. It reads all right. Viva Marconi—McClure.*

After this, Marconi was content to stay on at Wimereux for a time, partly to recover from a fractured kneecap sustained when his carriage from Boulogne to Wimereux overturned on a nasty corner, and partly to extend his work there. He felt able to spend increasingly longer spells out of England now, as the company was prospering and had already set up its first factory premises for the manufacture of components in a former furniture repository in the Essex town of Chelmsford, where the headquarters of The Marconi Company remain to this day. Chelmsford had a number of advantages, including its ready accessibility from London, but the over-riding factor was undoubtedly the wide, flat undeveloped countryside that was rightly considered to be eminently suitable for wireless experiments and tests.

Only one really anxious moment worried Guglielmo during the days at Wimereux. Among the many famous people who visited him there was the soldier Major Robert (later General Lord) Baden-Powell, hero of the South African War and future founder of the Boy Scout movement. Baden-Powell had been a keen admirer of wireless almost from the beginning, and Marconi, with his shrewd eye for a man who might be helpful to his cause, was especially anxious to create a notable impression. They both sent out messages to England but received no reply whatever. Marconi checked his equipment, and tried again, then again. Still no reply came from the Dover side. It was a filthy wet night, which made the utter silence in the comfortable wireless room all the more unendurable. Baden-Powell was first solicitous, then outright sympathetic, but he saw at once that Marconi was never a man to want sympathy, so he went about trying to help, indoors and outside where the 150 ft. tall, seven-stranded aerial mast heaved in the wind and rain. The soldier saw that to the inventor, this might well be serious, a real shattering of his own faith. The two men stood in the darkness at the foot of the mast, deeply disturbed if for different reasons, grim, and soaked through. Things really looked bad, when suddenly a bell rang in the building behind them and the operator yelled out: "South Foreland!" History records that the pair leapt together into the room faster than the proverbial scalded cat, each trying to be first to read the message clicketing out of the Morse inker: *Just back from supper. Anything happened your end*? When Marconi and his guest had finished laughing and he had recovered his usual composure, he knew one more thing: wireless stations, to be of any real value, must be continuously manned. And they still are, everywhere.

During the summer of 1899 Marconi was invited by the Royal Navy to equip three of its warships with radio for use during the naval manoeuvres. Accordingly the battleship *Alexandra*, and the cruisers *Juno* and *Europa* were equipped with Marconi apparatus and the commanding admiral shown the value of communicating with his fleet at ranges of up to eighty miles. This successful demonstration brought the company its first big government contract, to fit out twenty-eight ships and four land-stations with wireless. Gratifying though this was to Marconi, wider horizons were now beckoning him. On September 11th, 1899, Guglielmo Marconi, world scientist and aspiring man of the world, sailed for America on the Cunard liner *Aurania*. He was accompanied by a select few company officials and technicians, but no mother. And he arrived in New York wearing an immaculately trimmed moustache, a serious if unsuccessful gesture of masculine independence. The ostensible purpose of the visit was to radio reports of the America Cup yacht races off New York Bay for the *New York Herald*, to repeat the Kingstown success for a far wider audience. Marconi's first words to the waiting reporters as he descended the gangplank were confident if not very inspired: "We will be able to send the details of the yacht racing to New York as accurately and as quickly almost as if you could telephone them. The distance is nothing, nor will the hills interfere." This smacked far too much of the prepared statement to satisfy the American newspapermen, and there was much clamouring for interviews in the days that followed.

From the lively and outspoken reports published in various U.S. papers at this time, it is possible for us now to gain a vivid picture of just how the young man appeared to the keen-eyed New World, to which he had been only a name until now. Since the *Herald* had him under contract, not all the reports were flattering, and in retrospect, they are probably all the more valuable for that: "When the passengers began filing down the gangplank of the *Aurania*, few of the many who were on the pier recognised in the youthful, almost boyish-looking man the bearer of a name that has become distinguished in electrical circles . . . no bigger than a Frenchman and not older than a quarter century, he is a mere boy, with a boy's happy temperament and enthusiasm, and a man's nervous view of his life work. His manner is a little nervous and his eyes dreamy. He acts with the modesty of a man who merely shrugs his shoulders when accused of discovering a new continent. He looks the student all over and possesses the peculiar semiabstract air that characterises men who devote their days to study and scientific experiment . . . a serious, somewhat selfcentred young man who spoke little but then always to the point . . . When you meet Marconi you're bound to notice that he's a 'for'ner'. The information is written all over him. His suit of clothes is English. In stature he is French. His boot heels are Spanish military. His hair and moustache are German. His mother is Irish. His father is Italian. And altogether, there's little doubt that Marconi is a thorough cosmopolitan."

It was not long before New York was to see the true Marconi, the brilliant, sensitive man who walked his temperament like a jerking tightrope. Even before his luggage had been all unpacked at his Broadway hotel, a boiler exploded in the basement. Hysterical guests blamed this on the strange apparatus that had just arrived from England, and to calm down the terrific rumpus that ensued, Marconi and his men agreed to open their luggage trunks and show just how harmless their baggage really was. It was then that they found one trunk, full of the vital coherers for the receiving equipment, was missing. William Goodbody, one of the Marconi directors, and another man went back to the customs shed but could find no trace of it. Tight-lipped and white with rage, Marconi announced everything was finished and he was returning to England on the next ship out of New York harbour. Fortunately, the trunk was found at

Boston, having been inadvertently loaded into another ship leaving Liverpool for America on the same day as the *Aurania*.

Guglielmo was again tetchy and impatient when the races actually began but were held up through lack of wind for several days. By mid-October, though, the yachts raced, and over 1,200 wireless messages enabled readers on Broadway to know exactly what was happening off the New Jersey coast within sixty seconds or less. He was also bitterly disappointed that the subsequent demonstrations he gave the U.S. Navy and Army, especially on the warships *New York* and *Massachusetts*, and on Fire Island, were not the unqualified success he hoped for, and did not entirely convince the U.S. authorities. In fact, much American official opinion was frankly sceptical; many petty objections that Marconi was in no mood to answer. Part of the trouble lay in the fact that in the naval tests on the Hudson River there was good exchange of signals over thirty-six miles or so, but when one of the ships and a shore station began sending messages out simultaneously to the second ship, at ten-minute intervals, these were received all right, but the tapes proved unintelligible. This was caused by "double sending," each message blotting out the other. This merely showed Marconi the supreme importance of the work he had already been doing for some time on selective tuning of radio signals, the need to separate stations on to different wave-lengths. Then known as "electrical tuning," or "syntony," it was described by Kemp as "the tuning of a particular transmitter to a particular receiver, so that the latter will respond to the former and to no other, while the former will influence the latter and no other." This was to mark a big step forward in wireless technique, but it was not until 1901 that he was granted the famous "Four Sevens Patent," No. 7777, for selective tuning apparatus. With the tough chiefs of the U.S. Navy breathing down his neck and trying to quiz every inch of his equipment, Marconi could afford only to be cagey and non-committal about this grave fault and how it was going to be overcome.

So with a rather qualified success ringing in his ears (the newspapers had however declared "Marconi is a national hero"), Guglielmo returned to England on November 9th, 1899, on the liner *St. Paul,* leaving Goodbody behind to charter the American Marconi Company. The rest of his small team returned with him, but on the seven-day voyage to Southampton he preferred the company of two other people: McClure, the magazine proprietor, who was now a keen and usefully influential radio enthusiast, and a young lady from Indianapolis named Josephine Holman, with whom Guglielmo fell in love and was sure he was going

10 Marconi in ceremonial dress outside the House of Commons, when he was already a famous figure. This is one of a series of well-known personalities taken by Sir Benjamin Stone, M. P.


11 The cartoon figure of “Mr. Punch” offers Marconi the gratitude of the nation for the part played by wireless signals in saving 650 passengers on board the *Volpurno*. When the ship caught fire in mid-Atlantic in 1913 her signals were heard by ten ships. Their prompt arrival on the scene prevented disaster.

to marry. She came from a rich family, and the affair continued over the following year or so, during which worrying time Annie Marconi tried hard not to be possessive over her favourite son, and managed to be friendly towards the girl. But when in the spring of 1902, Guglielmo duly reported to his mother that Miss Holman had broken off their engagement, Annie's relief, although silent, must have been heartfelt. Degna Marconi comments: "I am sure his Josephine was beautiful since my father's eye for feminine beauty was unerring."

The trip back to England on the *St. Paul* was especially noteworthy for the publication on board of the first ship's newspaper ever to contain news received by wireless. Dated November 15th, 1899, Volume I, No. 1 of *The Transatlantic Times* was sold to passengers at one dollar per copy in aid of the Seamen's Fund, autographed by Marconi. It explained: "Through the courtesy of Mr. G. Marconi, the passengers on board the *St. Paul* are accorded a rare privilege, that of receiving news several hours before landing. Mr. Marconi and his assistants have arranged to work the apparatus used in reporting the Yacht Race in New York, and are now receiving dispatches from their station at the Needles. War news from South Africa and home messages from London and Paris are being received . . . As all know, this is the first time that such a venture as this has been undertaken. A Newspaper published at Sea with Wireless Telegraph messages received and printed on a ship going at twenty knots!" Contact with the Needles station was made at a distance of about sixty miles, and timed bulletins, some with Boer War reports, were printed as they came in. It was noteworthy that McClure was listed as Managing Editor, and Miss Holman as Treasurer.

## Chapter 4

# THE "BIG THING"—AND AFTER

As the twentieth century dawned, Marconi was more deeply immersed in his work than ever before. All his life he possessed the enviable faculty of being able to switch off completely all externals, focusing his mind intently—for days on end, if need be—on the single matter in hand. It was not an attribute that endeared him to those close to him, but it was a superb advantage in achieving a major scientific advance. Three main lines of activity absorbed almost all his waking life just now. First, inescapable yet the least attractive to him, was the mass of paperwork: accounting, planning, administrative, legal, that even in 1900 a new and expanding group of commercial companies brought in its train. Second, never out of his thoughts, was the technical pressing forward of his invention so that he could patent each step. Third, and now hardly a secret any longer, was what he always called "the big thing."

The first of these interests increased in April, 1900 with the formation of the all-important The Marconi International Marine Communication Company, Ltd, with three directors, including himself, from the original parent company, and eleven others representing British, French, German, Belgian, Italian and Spanish interests. Its aim was "to establish marine wireless telegraphy on a sound commercial basis practically throughout the world," and over the next half-century this organisation was to play a leading part in the history of radio communications at sea. Guglielmo still saw marine wireless as offering the greatest scope for his invention, and subsequent events proved him right, at least until after World War I. Perhaps not entirely to his liking, the first country to make a move was Germany, which equipped her crack Norddeutscher-Lloyd liner *Kaiser Wilhelm der Grosse*, built to snatch the North Atlantic Blue Riband from the British Cunarders, and the lighthouse and lightship at Borkum with Marconi International equipment. The Belgian vessel *Princesse Clementine*, plying between Dover and Ostend, followed suit, and soon many other vessels were fitted with radio and achieved highly successful results from their Marconi-trained operators, among them the Beaver line *Lake Champlain*, and the Cunard vessels *Lucania*, *Campania*, *Umbria* and *Etruria*.

At Marconi's insistence there was also set up the world's first school for training wireless engineers at the now select seaside resort of Frinton-on-Sea, Essex. This developed later into the existing Marconi College, which still sends out thousands of highly-trained radio men all over the world. It was becoming clearer now to everyone that Marconi was again so right, and that the greatest and least obstructed demand for wireless communication would come from the sea. Even here, though, many legal issues had to be resolved, for governments generally were loath to restrict radio signalling beyond their three-mile limits.

The second concern resolved itself for a time with the granting of the "Four Sevens Patent." After this was settled, Marconi, always a stickler for the courtesies and at the same time always a good businessman, wrote to the U.S. Navy Board explaining that he could not demonstrate his tuning instruments to them in the previous autumn because "they were not completely patented and protected." He was hoping for some lucrative contracts from the American Navy, but although both the British and the Italian navies paid his charges, the Americans considered them exorbitant and the deal fell through.

Marconi's third concern, his "big thing," had been in his secretive mind ever since he first crossed the Atlantic Ocean on the *Aurania*, when his companions often noticed "his blue eyes gazing steadily across the vast expanse of Atlantic rollers." With his inbuilt commercial and publicity flair, he knew that if he could link the Old World with the New by means of wireless, bridge that great Atlantic gulf with his ethereal messages, scepticism and scoffing everywhere would vanish, most of all in America. In spite of all the evidence to the contrary, he felt convinced that the marked curvature of the earth's crust over such a great distance would not affect his transmissions, "providing," as he himself put it, "the transmitter has sufficient power to hurl the waves across the ocean."

Although essentially a man of the nineteenth century, as was evidenced by such varied things as his whole family background and landed heredity, his impeccable manners and formal courtesy, his dress, his attitude towards women and his total reticence, Guglielmo Marconi was also a man of the twentieth. Intellectually and temperamentally he was always straining forward to it, even in those days in the attic rooms at the Villa Grifone. He was the last of the old practical, "one-man" scientists who made all their own basic equipment, and yet he was the first of the big-business inventors who guided the commercial fortunes of their discovery through the rocky channels of world-wide exploitation, patents and copyrights. Never too big to do any menial task himself, he nevertheless never lost sight for one moment of his own potential value as a world investment. Far from starving in some garret laboratory as a dreamy-eyed and hopelessly unworldly inventor, Marconi, as the London satirical magazine *Vanity Fair* unkindly pointed out, "never starved for more than five hours at a time." His daughter believes, probably correctly, that in scientific matters his supremacy stemmed from the humble belief that he was "a scientific vessel, a human instrument, chosen by a higher power to make a unique contribution to the progress of mankind. For his great discoveries he credited the Divine Will."

At any rate, he entered the twentieth century fully aware that he was going to transform it, even shape its whole future, as indeed he did. Never physically very robust, and always coddled by his mother, he had already developed into what his friend from Florence, Luigi Solari, called a *salutista*, meaning in a subtle degree someone who takes great care of his health, preserves himself well, yet is not actually a hypochondriac. Guglielmo always looked after himself physically in this way, and was now living to a strict and inflexible regimen, doubtless inspired by Annie but latterly enforced by Kemp, who looked after his boss as well as any mother. At the very least, it might be called good business—not subjecting a valuable asset to unnecessary wear and tear. The basis of his routine was sensibly simple: sound sleep and no more than adequate food. He normally tried always to get a good night's sleep, yet was never affected by the lack of it on occasion. Promptly every morning at 8 a.m. came breakfast: two soft-boiled eggs, bread-and-butter, marmalade and tea. This menu was decided upon and kept to strictly—because Marconi was sure that wherever he was in the world he could get it. He drank sparingly, usually only a little wine, and smoked the occasional cigarette, although never a cigar. Food as such never really interested him, and he hated large portions on his plate. He was very thin in these early years, and frequently suffered from colds and chills—the damp chilliness of his favourite surroundings, the sea, of windy coasts, and of foggy London, all pierced him to the marrow and he frequently wrapped up to the eyebrows with a brimmed tweed hat, fur collar, fur-lined topcoat and muffler. He probably inherited his mother's tendency to chills in cold wintry weather: certainly she was always advising him to "wrap up warmly" against the elements and the damp. He shaved off the moustache after the American jaunt, and remained cleanshaven ever afterwards, in striking if pale contrast to the majority of the men with whom he worked, who sported fine whiskers in great variety. Outstanding among them was Kemp, who had by now grown enormous gingery handlebar moustaches to match his shaggy mane of red hair.

Annie Marconi's own health was not entirely good, either, but she was more concerned now with her ageing and ailing husband, grouching his way from cure to cure in an effort to recapture his youthful well-being, and with "poor Alfonso," who also suffered from very bad health and who had now returned to Italy. Nevertheless, for some years yet she was to continue her solicitous fussing over Guglielmo, writing him long letters wherever he happened to be, telling him what clothes to wear, and so on.

All that remained now before the Atlantic venture could begin was a suitable base on each side. By July, 1900, he had found the English end of his projected link-up, a tiny place called Poldhu, breasting a 120-ft. high granite cliff on the rocky Lizard region of southwest Cornwall, overlooking the wide ocean. Professor J. A. Fleming had now officially joined the inventor as scientific adviser to the parent company, and with R. N. Vyvyan, a go-ahead engineer fast becoming another close and valued associate, he was given the job of equipping the station there. Marconi believed that to span the Atlantic he would need a two-inch spark gap powered by high frequency oscillating currents 100 times more powerful than anything used previously. After some trial and error, Fleming was able to provide this then amazingly high power by an ingenious device of his own, although even then the capacity was less than one-tenth of that used today by an ordinary broadcasting station.

After various daunting setbacks, including the hostility of certain Americans at one of the sites originally selected in Massachusetts, and the disastrous collapse in fierce storms within weeks of each other of the wooden masts at both Poldhu and the station eventually established at Cape Cod (where Vyvyan was lucky to escape with his life), Marconi decided to cut his losses and move northwards into Newfoundland. This was then a separate British colony, and was still to become a Canadian province, and he chose the fishing port of St. John's as his base. Guglielmo was becoming typically impatient, for it was now nearly the end of 1901. "I really had no doubts about the ultimate success of the experiment," he said, "but I was anxious to refute as soon as possible the scepticism which surrounded it." Again there were last-minute hitches and delays, not least when the hour for departure from England came and Kemp could not be found. Faithful as ever, he had no doubts of the success they would achieve, and the supply of whisky he had gone to lay in at the eleventh hour was not for a victory toast, but rather that his "Chief" should be well protected against the Atlantic cold of icy Newfoundland, land of fogs, rain and gales.

Here is Marconi's own coolly factual account of what happened: "On November 26th, 1901, I sailed from Liverpool in the liner *Sardinian*, accompanied by two assistants, Messrs. Kemp and Paget. As it was clearly impossible at that time of the year, owing to the inclement weather and especially in view of the shortness of the time at our disposal to erect high poles to support the aerial, I had arranged to have the necessary aerial supported in the air by a small captive balloon, and so we took with us two balloons as well as six kites. We landed at St. John's on Friday, December 6th, and the following day, before beginning operations, I visited the Governor, Sir Cavendish Boyle, the Premier, Sir Robert Bond, and other members of the Ministry, who promised me their heartiest cooperation and placed the resources of every department of the Government at my disposal in order to facilitate my work. They also offered me the temporary use of such lands as I might require for the erection of depots at Cape Race, or elsewhere, if I should eventually determine to erect the wireless stations which they understood were then being contemplated. After taking a look at the various sites which might prove suitable, I considered that the best one was to be found on Signal Hill, a lofty eminence overlooking the port and forming the natural bulwark which protects it from the fury of the Atlantic gales. On top of this hill there is a small plateau of some two acres in area which I thought very suitable for the manipulation of either the balloons or the kites. On a crag on this plateau rose the new Cabot Memorial Tower which was designed as a signal station, and close to it there was an old military barracks which was then used as a hospital. It was in a room in this building that I set up my apparatus and made preparations for the great experiment.

"On Monday, December 9th, barely three days after my arrival, I began work on Signal Hill, together with my assistants. I had decided to try one of the balloons first as a means of elevating the aerial, and by the Wednesday we had inflated it and it made its first ascent during the morning. Its diameter was about fourteen feet and it contained some 1,000 cubic feet of hydrogen gas. Owing, however, to the heavy wind that was blowing at the time, after a short while the balloon broke away and disappeared to parts unknown. I came to the conclusion that perhaps the kites would answer better, and on Thursday morning, in spite of the furious gale that was blowing, we managed to elevate one of the kites to a height of about four hundred feet. It was a bluff, raw day; at the base of the cliff, three hundred feet below us, thundered a cold sea. Oceanward, through the mist, I could discern dimly the outlines of Cape Spear, the easternmost reach of the North American continent, while beyond that rolled the unbroken ocean, nearly two thousand miles of which stretched between me and the British coast. Across the harbour the city of St. John's lay on its hill-side, wrapped in fog.

"The critical moment had come for which the way had been prepared by six years of hard and unremitting work in the face of all kinds of criticism and of numerous attempts to discourage me and turn me aside from my ultimate purpose. I was about to test the truth of my theories, to prove that the three hundred patents that the Marconi companies and myself had taken and the tens of thousands of pounds which had been spent in experimenting and in the construction of the great station at Poldhu, had not been in vain.

"In view of the importance of all that was at stake I had decided not to trust to the usual arrangement of having the coherer signals recorded automatically through a relay and a Morse instrument on a paper tape, but to use instead a telephone connected to a self-acting coherer, the human ear being far more sensitive than the recorder. It was shortly after midday on December 12th, 1901, that I placed a single earphone to my ear and started listening. The receiver on the table before me was very crude —a few coils and condensers and a coherer, no valves, no amplifier, not even a crystal. I was at last on the point of putting the correctness of all my beliefs to the test. The experiment had involved risking at least £50,000 to achieve a result which had been declared impossible by some of the principal mathematicians of the time. The chief question was whether wireless waves could be stopped by the curvature of the earth. All along I had been convinced that this was not so, but some eminent men held that the roundness of the earth would prevent communication over such a great distance as across the Atlantic. The first and final answer to that question came at 12.30.

"Suddenly, about half past twelve there sounded the sharp click of the 'tapper' as it struck the coherer, showing me that something was coming, and I listened intently. Unmistakably, the three sharp little clicks corresponding to three dots sounded in my ear; but I would not be satisfied without corroboration. 'Can you hear anything, Mr Kemp?' I said, handing the telephone to my assistant. Kemp heard the same thing as I, and I knew then that I had been absolutely right in my calculations. The electric waves which were being sent out from Poldhu had traversed the Atlantic, serenely ignoring the curvature of the earth which so many doubters considered would be a fatal obstacle, and they were now affecting my receiver in Newfoundland. I knew that the day on which I should be able to send full messages without wires or cables across the Atlantic was not far-distant and, as Dr. Pupin, the celebrated Serbo-American electrician, very rightly said shortly afterwards, the faintness of the signals had nothing to do with it. The distance had been overcome and further development of the sending and receiving apparatus was all that was required.

"After a short while the signals stopped, evidently owing to changes in the capacity of the aerial wire which in turn were due to the varying height of the kite. But again at 1.10 and at 1.20 the three sharp little clicks were distinctly and unmistakably heard, about twenty-five times altogether. On the following day the signals were again heard though not quite so distinctly. On Saturday a further attempt was made to obtain a repetition of the signals but owing to difficulties with the kite we had to give up the attempt. However, there was no further doubt possible that the experiment had succeeded and that afternoon, December 14th, I sent a cablegram to Major Flood Page, managing director of the Marconi Company, informing him that the signals had been received but that the weather made continuous tests extremely difficult. That same night I also gave the news to the Press at St. John's whence it was telegraphed to all parts of the world."

Rarely can such an astounding event have been described by its originator so calmly and unemotionally; but that was typical of the man.

The engineers at Poldhu swiftly heard by submarine cable that their unfailing transmission of the Morse letter S (three dots) as agreed at a fixed speed every ten minutes between 3 p.m. and 7 p.m. Greenwich Mean Time, with five-minute rests in alternation, had crossed the Atlantic, and there was great jubilation. At St. John's, with the wind howling round their "small dark room furnished with a table, one chair and some packing-cases," as Paget was later to describe it, with their whisky and mugs of cocoa and slabs of bread and cheese, the excitement was kept well in check, as was Guglielmo's custom. He did permit himself a joyful little cable to Giuseppe at Pontecchio, however.

Marconi's inevitable use of the undersea cable service to spread his astonishing news to the world was ironical, since the cable companies, with their vested interest in Trans-Atlantic communications as they were, swiftly proved to be his bitterest enemies. They soon claimed that his sending of messages from England to Newfoundland violated their monopoly rights in the latter country. Fortunately the Canadian Government immediately offered him a subsidy of £16,000 for the erection of a completely new station on their territory. In the circumstances, this was a superbly well-timed and highly generous offer, and it led to the establishment of the famous Marconi station at Glace Bay, Cape Breton Island, Nova Scotia, a cliff headland site not very far round the coast from St. John's, and one which was to see a lot of Marconi in the years immediately ahead.

As before, Marconi's achievement received much praise and at the same time abundant scepticism. *The New York Times* reported: "Guglielmo Marconi announced tonight the most wonderful scientific development of recent times," and the London *Times* gave the news in similar vein and supported him to the hilt. By contrast, the London *Daily Telegraph*, among many other papers, sought to pour cold water on the whole thing: "There is an indisposition .... to accept as conclusive Signor Marconi's evidence that the problem of wireless telegraphy across the Atlantic had been solved by the young inventor. Scepticism prevailed in the City. 'One swallow does not make a summer,' said one, "and a series of "S' signals do not make the Morse Code!' The view generally held was that electric strays and not rays were responsible for actuating the delicate instruments recording the "S's' supposed to have been transmitted from near the Lizard .... Some attributed these wandering currents to the old trouble—earth currents, others to the presence of a Cunarder fitted with Marconi apparatus which was, or should have been, within 200 miles of the receiving station at St. John's on the day of the experiment."

Always one to recognise and appreciate loyalty and support in the face of this kind of thing, Marconi never forgot the favourable reaction of the London *Times*. In 1935, on the occasion of that newspaper's 150th anniversary, it published a letter from him which he said he was particularly glad to write because he could "never forget the inestimable assistance and support" which *The Times* gave him during his early days of wireless experiments, especially in 1901. "At that time and for long afterwards," he wrote, "certain important sections of the technical press in this country were against me, and spared no efforts in their determination to discredit both me and my work on long-distance wireless communication. From the first, however, *The Times* declared its belief in me, and was swift and forceful to rebuke those who persisted in a policy of disparagement."

These well-chosen words are very revealing of Marconi's nature, and his feelings in 1901 and for many years afterwards. The sheer magic of the "big thing" undoubtedly converted many waverers to outright disbelief, among them Thomas A. Edison himself, who at first declared his belief that the feat was simply impossible. It is to Edison's credit that he soon changed his views, saying that his faith in the integrity of the young Italian was sufficient ground for accepting his claim. He added: "I would like to meet that young man who has had the monumental audacity to attempt and succeed in jumping an electric wave across the Atlantic." Even Sir William Preece was reported as saying: "We shall want more information than we have at present . . ." Sir Oliver Lodge said of Marconi: "I sincerely trust that he is not deceived . . ." Others, less distinguished scientifically, muttered darkly of trickery or innocent deception by lightning or ground currents.

Guglielmo as usual took both the praise and the accusations in his stride. He knew what he had done, and that was all there was to it. But he was still to learn exactly *why* he had been able to do it. He returned to England to attend to some company business and spend a short while with his mother, of whom he said: "She is the only person on earth who understood my misgivings and trepidation when I left for Newfoundland." Now there was no further need for trepidation, and it is clearly partly because he did sometimes rather enjoy a fight, when he knew he was in the right, that he left for Canada again very soon. He wanted to knock the doubters and sceptics out of the running, and as for the cable companies, he could only marvel at their short-sighted, almost Luddite behaviour. There is no doubt at all that large sections of the then swiftly growing electrical industry as such feared greatly for the possible competition of a "wire-less" system of communication. If only they had had the vision of the extraordinary young man they hated so much, had seen just how astonishingly their whole industry would one day grow simply because of his invention!

This time, Marconi wanted independent, impartial witnesses of what he was achieving, as well as the establishment of a west-to-east Transatlantic link. The ship involved was the *Philadelphia*, and with a picked team of six on board, he sought to discover exactly how far out into the Atlantic messages from Poldhu could be received and understood. It was a well-planned trip, specifically designed by the inventor "to blazon the truth of what wireless could do to a doubting world." This time, he had skilled, impartial and unimpeachable witnesses—Captain A. R. Mills, Chief Officer C. Marsden, and others, including some of the ship's passengers invited to watch the tests in the radio cabin. The St. John's receiving apparatus was again used, but the big square wire aerial fixed to the liner's 170 ft. tall mast enabled the receiver to be permanently tuned into Poldhu. In Newfoundland this was impossible because of the jerking altitude of the kite. This

12 Marconi in the trenches at Monte Grappa in 1917. As an Italian officer in charge of wireless communications he frequently visited the war front.

13 Dame Nellie Melba, famous prima donna, during a recital in 1920 which was the first ever officially advertised programme of broadcast entertainment. The programme was received in most of Europe and as far afield as Persia.

time, too, the messages were recorded on the Morse inker for all to see with their own eyes. Readable messages were received from Poldhu at distances up to 1,551 miles, and the test letter "S" up to 2,099 miles, which was almost as good as the electronic jump of 2,170 miles achieved at St. John's.

Marconi had the master and officer verify and sign his Morse tapes so that this time there could be no doubt whatever. As he showed his tapes to the waiting pressmen in New York his comment was grimly laconic: "This merely confirms what I have previously done in Newfoundland. There is no longer any question about the ability of wireless telegraphy to transmit messages across the Atlantic." The hordes of doubters were swiftly silenced, although some scepticism remained, and some understandable disbelief that radio could ever be anything more than a toy. After all, radio as a worldwide reality was still nearly a quarter of a century away, and not until twelve years later, in 1919, was the first Transatlantic transmission of human speech to be achieved by D. T. Ditcham. But the visual proof secured on board the *Philadelphia* helped a lot. As the still faithful *McClure's* magazine said at the time: "Marconi and the ship's officers and others aboard the *Philadelphia* heard the tick and, looking at the tape, saw the dots and dashes which you or I or anybody can still see.

When a machine does a thing, we humans believe; so long as a man stands between, we doubt."

Both as a man and as a public scientific figure, Guglielmo was now learning fast. His boyishness was vanishing before a more mature, if still diffident manner. Within a year or so of the *Philadelphia* tests, he was to be described as "the most interviewed man in the world," and one of the many ways in which he was learning fast, was how to deal with the press and their awkward questions. Some of the replies he gave round about 1902 to various queries from reporters again reveal his inborn confidence in his work and his growing self-confidence facing the world. Asked about the possible distance over which a wireless message might be sent, he said: "I will say that it is a matter depending solely on the strength of the apparatus used. As for the curvature of the earth affecting the currents, as the cable people thought it would, that has been proved untrue. That objection on their part, though, I think, was rather imaginary, than a real one. The wish was probably father to the thought." When asked about the possibility of sending a message right round the world back to the same place, he retorted: "Well, it's possible, but I do not think it is what you would call a paying investment." As to Italian wireless: "In Italy there is really extraordinary scepticism about wireless communication." And as for England, where the Postmaster General was now saying that the operations of the Marconi Company might interfere with the experiments of the Admiralty: "Well, the British ships are using my instruments. The Government is paying $25,000 per annum for the use of my apparatus in a very few vessels. If the powers should decide to make me take away my station and would pay, as they would have to, for the privilege of making my experiments themselves, then I would think I had made a good bargain . . . The Admiralty's instruments are of the old style and were put in before I solved the problem of attuning to prevent inter-communication. So you see, we might interfere with the Government, but they cannot interfere with us. England is not the country in which I hope to accomplish much. They are a little old-fashioned over there, you know. Some of the people do not even want the wireless system tested. They say it is too much trouble. Furthermore, England is not the proper field in which to make great strides in testing the land advantages of the system, which is as adaptable to inland and short-distance service as it is to transoceanic service." When a reporter enquired: "How about a station in South Africa?" Marconi replied, with a smile: "Let's finish the Atlantic first!" How Giuseppe must have been chuckling with glee when he heard about all this. Here, after all, was a true Marconi!

It was left to Fleming to remind the world of the real marvel of it all. "When it is realised," he wrote to *The Times*, "that these visible dots and dashes are the result of trains of intermingled electric waves rushing with the speed of light across the intervening miles, caught on one and the same short aerial wire and disentangled and sorted out automatically by the two machines into intelligible messages in different languages, the wonder of it all cannot but strike the mind." Fortunately for the history of twentieth century man, Marconi never lost that sense of wonder.

## Chapter 5

# NOBEL PRIZE-WINNER AND WORLD FIGURE

Astonishing though the Atlantic successes were, and vital in their sheer publicity value, Marconi knew all along that they were only a beginning. Yet even he could scarcely have imagined just how arduous and rough the road was to be for him over the next decade or so. He can scarcely have foreseen just how many battles he would have to fight in the years that followed the heroic achievements of 1901-1902. There were to be problems on almost every level—personal, scientific, commercial, even political, but he was to win through them all, although not completely unscathed.

Annie Marconi reconciled herself now to seeing less of her famous son. She knew that he was steadily growing out of the special relationship that had once meant everything to him. Old Giuseppe was ailing and becoming ever more crotchety, his own parochial success swamped by the achievements of his son. Yet it is pleasing to record that in 1903, when he was already over eighty, Giuseppe was to see that son return to Italy in splendour to receive the honorary citizenship of Rome. His son a Roman citizen—greatest of Italian privileges! The old man was completely overwhelmed with pride and joy. Guglielmo took his parents to the capital, where they were feted through the streets in a state coach drawn not by horses but by cheering students from the University. At the University of Bologna earlier, Professor Righi made a speech of welcome so cordial that the father was reduced to tears and the son to embarrassed speechlessness.

Gratifying though it was, the excursion to Rome proved to be Giuseppe's last major effort, and he died early in 1904. In his will he left the Villa Grifone not to his eldest son, as was the usual custom, but to Guglielmo, who kept the estate on throughout his own life, although for long periods it was unoccupied. The old man was rather a pathetic and lonely figure at the last, dourly bitter with age, but he was always especially proud of the little plaque erected on a wall at the Villa by the Italian people, which read:

> Honour to the merit of
>
> GUGLIELMO MARCONI
>
> who in this house
> when still very young

carried out his first
experiments, and by his
ingenuity and study
invented the wireless
telegraph in the year
1895, admired by Italy
and Europe.

Annie Marconi returned to England, where she lived for sixteen years more, thinking always of Guglielmo whom she rarely saw, cared for by the devoted Alfonso, and oddly so homesick for Italy. As it happened, Guglielmo did not attend the funerals of both his parents, pleading pressure of urgent company business. The past died quickly for him.

In 1902, however, the high spot was the work Marconi did aboard his first "floating laboratory." This was the cruiser *Carlo Alberto*, star of the Italian Navy, which was placed at his disposal in July, thanks to the good offices of Luigi Solari, then a young naval lieutenant, who had applied direct to the Italian King Victor Emmanuel, no less. Installation work at Glace Bay had been delayed, and Marconi had just patented his magnetic detector, with which he hoped for greater sensitivity in reception than was possible with the coherer, always the weakest part of his apparatus. The prototype he made himself at the Poole station with fine flower wire, and this improvement soon became standard equipment, especially for ships. So Guglielmo felt this would be a good chance to test it at sea. The *Carlo Alberto* was in British waters for the Coronation Fleet Review for King Edward VII, but when that monarch fell ill with appendicitis, and the review was postponed, she was ordered to the Russian naval base at Kronstadt, where King Victor Emmanuel was visiting the Czar. Marconi had very little time to equip the vessel, and was in fact in London when the plans were changed. Luckily Kemp worked all night to rig everything up, assisted by a young midshipman, Giuseppe Raineri-Biscia, later to be a distinguished Italian admiral, who also came from Bologna.

At Kronstadt, Guglielmo demonstrated his equipment to his King and the ruler of All the Russias, and there were great festivities of a kind that only that era could produce. There was one very significant caller to the cruiser as she lay in Kronstadt Harbour. Helped on board by an Italian sailor, he said: "I want to pay my respects to Marconi, the father of wireless." He was Alexander Stepanovitch Popov, another pioneer worker in radio, who had discovered as early as 1895 that a coherer could detect the presence of electrical storms from a distance. In view of the fact that Popov has been widely given credit for the "invention" of wireless himself, and in Soviet Russian propaganda is usually named as the only radio pioneer worthy of mention, his remark on that day in July, 1902, needs to be remembered.

The *Carlo Alberto* subsequently cruised to Kiel and thence back to Spithead for the Coronation Review, after which she visited Poole, Plymouth, Spain, Portugal, North Africa, Sardinia, Italy, and later, Nova Scotia, for the inauguration of the Glace Bay station. On board, Marconi over-worked himself, meeting once again the phenomenon of getting good transmission results by night, but only moderate ones by day. This so-called "daylight" effect had not been fully understood: it concerns the ability of the electrified layer of the ionosphere to reflect back more of the radio waves impinging on it during darkness than during the sunlight hours, a simple enough phenomenon, but one that was to baffle the inventor for some time. Indeed, he first believed that sunlight acted "as a kind of fog" to radio waves, and on at least one occasion on board the cruiser was heard to exclaim violently in Italian: "Damn the sun! How long will it torment us?"

At first, results from the new, more powerful equipment set up at Glace Bay were disappointing, and after much trial and error, the aerials were improved sufficiently to pick up Poldhu. Aerial trouble led Marconi not long after to perfect his directional long wave aerial, which gave much better results when pointed correctly towards the receiving station, using longer waves than those previously thought to be best. Still, Marconi and his men were groping more or less in the unknown, handling forces not fully mastered with equipment that seems today quite laughably crude and inefficient. The big power plant used at Glace Bay leapt enormous sparks across the metal balls of the transmitter, illuminating the little clapboard hut like lightning, deafening the engineers like thunder-crashes. On December 5th, 1902 came a cable message from England, reporting the first success they had achieved at all: *Weak signals for the first half-hour, nothing doing next three-quarters, last three-quarters readable and recordable on tape.*

This was nowhere near good enough, and it was not until December 16th, at seven o'clock in the morning, that Guglielmo, working the yard-long wooden pump-handle of the sending key, tried again to "raise Cornwall." "Better put your hands over your ears," he warned his staff as usual, and started to call Poldhu with three Morse dots—"S". *Crash! Crash! Crash!* went the sparks, again and again. In a few minutes he cried "Here they are!" as the Morse inker transcribed in Morse SN—I understand. At the end of that session, Poldhu was able to report the joyful news: *Readable signals through two hour's programme.* The men dashed outside in the snow, dancing madly with joy. Guglielmo was equally jubilant, but he did not show it. As always, his work was his life, completely. Emotion did not really come into it. An onlooker at Glace Bay at this time, Dr. George Parkin, noted: "I was struck by the instant change from nervousness to complete confidence which passed over Mr. Marconi's face the moment his hand was on the transmitting apparatus—in this case a long wooden lever or key."

Marconi looks out from the old photographs taken during those hectic years at Glace Bay, Cape Cod, Poldhu and elsewhere, a slim, fastidious-looking figure in long overcoat or tweed suit, flat cap, tweed hat or Russian-type fur hat, and heavy boots, totally absorbed in his self-chosen role, something of an incongruous figure in such primitive surroundings and a very marked contrast to the portlier, aristocratic-looking Marchese of the later years.

In 1904, soon after his father's death, Guglielmo was thirty, full of anxiety about the future of his work and of his company, whose finances were decidedly rocky, partly owing to the huge expenditure necessary at Glace Bay, partly owing to many contract difficulties. Even his many demonstrations to date did not seem to have awakened the vital enthusiasm he wanted to see in hard-headed businessmen on both sides of the Atlantic. His nerves, his hopes, even his health, were alike in bad shape. In a moment of bitterness, he told Luigi Solari: "A man cannot live on glory alone."

He found relief from these worries in love. In the late summer of 1904 he met Beatrice O'Brien, heiress daughter of an Irish peer, Baron Inchiquin. She was nineteen, totally innocent of love, incredibly naive. As Marconi's (and her) daughter put it: "My father was anything but an impulsive man, yet the moment he saw her he knew that he wanted to marry this high-spirited country girl, so beautiful, so naive and so abominably dressed ("The dress she had on was *awful*!" he always said.) Guglielmo, always susceptible to feminine charm, particularly of the youthful variety, had really fallen this time. He pursued her ardently, never doubting that she would soon be his wife, but in the cramping, even stifling Edwardian fashionable society in which she moved, their courtship proved stormy and uncertain.

At this time, Guglielmo took more and more time off from company work at Poole and became for a while a sought-after guest at London charity balls and the like, driving up from the coast in his big Mercedes, one of the first cars of its kind in England, and capable of fully 51 miles an hour! It was at one such ball, at the Albert Hall, organised by his Bea's mother, now a widow, that he proposed unromantically to her on an iron staircase of the outer lobby. Although she had been something of a tomboy in her childhood, and had enjoyed the company of other beaux, Bea was undecided about this strange, aloof, foreign admirer, although she immensely enjoyed the facts of his fame. At first she refused him, and poor Guglielmo, playing very effectively the unfamiliar role of rejected suitor, and "wearing his broken heart on his well-pressed sleeve," left for distant parts, Turkey, Bulgaria, Roumania. But business was still in his head and he furthered the company interests wherever he went.

As it happened, this mad flight abroad brought Marconi little but trouble in the long run. He caught a dose of malaria whilst in the Balkans and was to be a victim to its recurrent after-effects of fever and chills for many years. And his constancy and obviously genuine feeling melted the heart of this gay young girl, so that one day when they were walking on Brownsea Island, in Poole Harbour, and he proposed to her again, she accepted. There was family opposition to contend with, just as there had been forty years before when Giuseppe Marconi and Annie Jameson had wanted to marry, but as so often happens, this merely strenghtened Bea's desire to become his wife. Fortunately in the eyes of her family, he was famous and although foreign and slightly mysterious was not a member of the dreaded

Roman Catholic faith. He seemed to them fairly wealthy, with good prospects, and in spite of spiteful rumours about his fondness for a certain Princess Giacinta, they believed him to be faithful in intent and obviously a "gentleman."

So the Inchiquins gave their blessing to the match, and the pair were married with great pomp at St. George's Church, Hanover Square, London on March 16th, 1905. Over 350 congratulatory telegrams arrived at the reception at Lady Inchiquin's house near Marble Arch from all over the world, and lush gifts arrived in almost equal abundance. From Russia Popov sent a sealskin coat and a silver samovar. Guglielmo gave his bride two wedding presents—a flashy coronet of Brazilian diamonds (said to have been suggested to him by her shrewd mother) and, of all things, a bicycle; "That was really his own idea," she said. They honeymooned with her relatives at Dromoland Castle in Ireland, where Marconi was glad to escape from the public attention that had overwhelmed them in London, when huge crowds besieged Hanover Square. He got on surprisingly well with his mother-in-law, who nicknamed him rather improbably "Marky"—it is said because she could not correctly pronounce his Christian name. There is no doubt whatever that "Marky" was deeply infatuated with Bea, but she swiftly had a foretaste of the kind of husband he would prove to be when there were temperamental tiffs on the honeymoon and he walked alone in the woods to cool off, and worse still, when he cut short their stay in Ireland after only a week "Because of business in London."

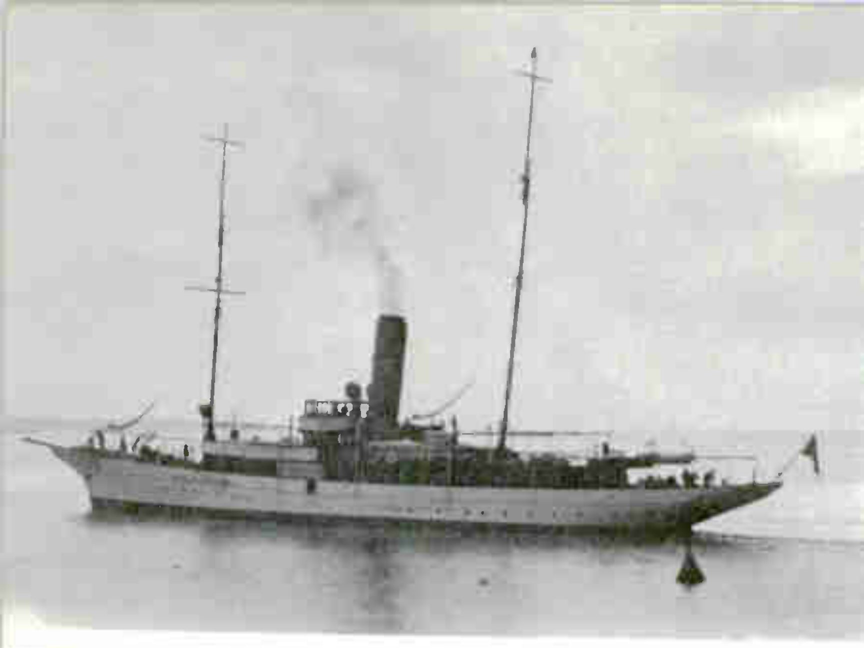
On Guglielmo's side, he not only realised his wife was but a child—he regrettably treated her as such, teaching her the Morse Code, flying into paroxysms of rage when she went out for a walk alone in London, baffling and confining her at every step. He discovered on their return to London that she had never stayed at an hotel in her life, could just not get used to being addressed as "Ma'am," let alone Signora Marconi. Above all, he quickly came to the awful realisation that by nature she was a born flirt, "and, innocent as a baby, incapable of suppressing her adorable, flashing smile at every male who came near her." Marconi was sufficiently Italian to be seized with violent, insensate jealousy at all times. Bea was not unnaturally apprehensive about marriage: he was probably too self-absorbed to be. In any event the temperamental and hereditary differences between them were too great for the union ever to be happy, and although there were four children, Lucia, born in 1906, whose death after only a few weeks was a shattering blow to Guglielmo; Degna, born 1908; Giulio, born in 1910 at the Villa Grifone since his father, certain that their next child would be a boy, wanted him to have full Italian citizenship; and another daughter, Gioia, born in 1916, the couple gradually drifted apart and there was a divorce in 1927.

In the early years, however, the growing rift was well concealed from the public gaze, although both pairs of eyes were to wander elsewhere, Marconi's undoubtedly first. The famous London satirical journal *Vanity Fair*, publishing in 1905 a "Spy" cartoon of him with well-greased hair, high collar and hands untypically in his trouser pockets, and knowing nothing of his marital problems, his fears of his wife's extravagance, his commercial money worries, his nervous irritability and the complete lack of all domesticity with which his impractical and innocently unworldly wife was having to cope, concentrated instead on an amusing appraisal of his life and character. Under the heading "Wires Without Wires" (itself a good joke against the radio apparatus of the time), it dubbed him Bill (Guglielmo being the Italian for William): "He is a quiet man with a slow, deliberate manner of speech, and a shape of head which suggests an unusual brain . . . Bill was educated at Leghorn under Professor Rosa, and afterwards at Bologna University. He first attempted to send wires without wires upon his father's land . . . His system is used exclusively at Lloyd's and in the British and Italian Navies. It has made the Atlantic still less endurable for tired brains by providing liners with a daily paper. He has alarmed the Chinese with his devices at Pekin and Tien-Tsin, forcing them to compose special prayers against foreign devils and all their works. He has been the cause of a petition from the Cornish fisherfolk, who suggested that the Government should put him down before his electrical sparks ruined the weather. Lastly, to fill the cup of his *Sins*, he has sent messages across the Atlantic, and created amongst shareholders in cable companies a feeling which resembles the personal uncertainty of chickens under a hawk. He is a hard worker, displaying the greatest resolution before unexpected difficulties. He rides, cycles, motors. Of music he is a sincere admirer. Being half an Irishman, his lack of more humour is prodigious."

In 1906 the Marconi Company decided that the Poldhu station was too restricted for the Transatlantic sending of what were now known as "Marconigrams" and the huge aerial set-ups (some a mile long) that the inventor was planning. So a completely new and much bigger station was established on the spongy peat-bogs of Connemara, at a place called Clifden, miles from civilisation. It was planned to burn much of the peat there as fuel for the huge 300 kilowatt steam generating plant, and after some delays, regular messages went back and forth to Glace Bay, with an unlimited public wireless telegraphy service beginning early in 1908. Only four years had elapsed since the first signals had reached Poldhu from Glace Bay, and this was therefore a considerable achievement, and for a time the only delays in the links between London and Toronto and New York were caused by the overloaded and somewhat unreliable land-line connections at each end. R. N. Vyvyan was to comment later: "Only those who worked with Marconi throughout these four years can realise the wonderful courage he showed under frequent disappointments, the extraordinarily fertility of his mind in inventing new methods to displace others found faulty, and his willingness to work, often sixteen hours a day, at a time when any interesting experiment was being tested."

Nothing cheered "The Old Man," as his staff now began to call him among themselves, more than the outcome of the terrible events of the early morning of January 23rd, 1909. At 5.30 a.m. the proud, 15,000-ton White Star liner *Republic*, less than a day out from New York and carrying 461 passengers and 300 crew, was run down in the darkness and fog by the Italian steamer *Florida*, carrying over 800 poor Italian emigrants. The liner was cut down to the water-line, her sides slashed open, her

14 Cristina Bezzi-Scali, Marconi's second wife, at a charity ball in 1929, two years after her marriage. She is dressed as Bona Lombardi Brunoro, an Italian heroine of the fifteenth century.




15-16 The *Elettra*, the ocean-going yacht fitted out for Marconi in 1920 as a radio laboratory, with particularly tall masts for receiving purposes. By 1924 radio broadcasting had progressed far enough to be used in political campaigning. Here a candidate, in between speeches, entertains the crowd with a wireless concert.

dynamos stopped, plunging the vessel into complete darkness. Her wireless cabin was badly damaged, but fortunately, her accumulator batteries were intact and so messages could still be sent. Her young radio operator, Jack Binns, found he had just enough power to call the mainland wireless station at Siasconcet: *We are shipwrecked. Stand by for captain's message.* His Marconi receiver clicked back in reply from the American coast: *All right o.m. (old man). Where are you?*

Binns gave the *Republic's* position, and soon five other ships were sent to the rescue, the first, the White Star liner *Baltic*, picking up the alarm call and altering course by 6 a.m. He could hear the other ships talking to the shore, but his own spark was too weak to reach them direct. Although his cabin was a shambles lit only by an oil-lamp, Binns stuck to his key for many hours, sending out over 200 messages, many of them directing the *Baltic* after her arrival on the scene into the best position for picking up survivors in the dense fog. He was the first of a new kind of twentieth century hero, the dauntless wireless operator sticking to his post in disaster, and thanks to his skilful use of radio over 1,700 lives were saved. This meant much to Marconi, who presented him with a gold watch at a special ceremony at the Marconi Company offices, now at Adelphi, London.

There were soon to be other instances, too, of wireless saving lives at sea, culminating in the much better-known *Titanic* disaster of April 14th, 1912, when this, then the largest ship in the world, struck an iceberg on her maiden voyage. Her wireless operator, Jack Phillips, never deserted his post in his frantic efforts to send out distress signals clear enough to attract passing shipping, particularly the liner *Carpathia*. On this notable occasion, he transmitted both the old distress signal CQD (*come quick, danger*), (in Morse the hard to send —·—· / ——·— / —··), and the newly devised one, the now universal SOS, far easier to send in Morse as ··· / ——— / ··· This was the first time the SOS signal was used in earnest. Although Phillips was one of the 1,503 unfortunates who lost their lives when the *Titanic* finally sank on that dreadful night, the unceasing efforts of Phillips and his assistant, Harold Bride, undoubtedly saved the lives of the 703 people the *Carpathia* did manage to pick up. Marconi said afterwards, with deep feeling: "It is worthwhile having lived to make it possible for those people to be saved . . . all those who have been working with me entertain a true feeling of gratitude that wireless telegraphy has again helped to save human lives." Lord Samuel, the Postmaster General, declared: "Those who had been saved had been saved through one man, Mr. Marconi, whose wonderful invention was proving not only of infinite social and commercial value, but of the highest humanitarian value as well."

This was further underlined the following year when the British steamship *Volturno*, fully laden and carrying over 600 emigrants from Rotterdam to New York, caught fire in heavy seas in mid-Atlantic. Her radio men, Seddon and Pennington, managed to call up no fewer than ten large ships to her aid, and after many agonising difficulties in the gale, over 650 lives were saved and a disaster of *Titanic* proportions miraculously averted. Marconi was very conscious of what had been achieved, and presented the *Volturno's* two wireless operators with gold watches to commemorate their splendid work.

But some lives had been lost, and once again, as in 1912, he was bitterly aware of the need for many improvements in wireless at sea, notably much higher transmitting power, and the pressing need for the allocation of specific wave-lengths for shipping—as he himself explained: "Some ships failed to hear the *Titanic's* call for help because they were receiving news bulletins from Cape Cod. With two operators, one could be working the news, the other—on any ship properly equipped—could be listening for distress signals, which would not interfere with the long-distance messages." He felt that the answer lay in making any distress call from one ship picked up by another ring a loud bell, like a fire-alarm, but it was not until 1927 that the now almost universal auto-alarm become compulsory equipment on many ships.

Whatever his misgivings—and he gave interesting and concerned evidence before the Government inquiry into the loss of the *Titanic* —he knew from many manifestations of it that public gratitude and esteem was vast and world-wide. *Punch* summed it up well just after the *Volturno* episode by publishing an excellently-drawn cartoon by L. Raven Hill of him seated in a radio cabin, with "Mr. Punch" telling him: "Many hearts bless you today, Sir. The world's debt to you grows fast." At an enthusiastically clamorous meeting of the New York Electrical Society, Michael Pupin suggested: "If we must call our aerial waves by some name let us not call them Hertzian waves but Marconi waves. They are his."

This feeling had been growing for many years in almost all countries, and Guglielmo's Freedom of Rome had been followed by many other international awards, gold medals, diplomas and the like. But none he received was to be so distinguished, or to give him such genuine pride, as the award on November 15th, 1909 of that year's Nobel Prize for Physics. Marconi was then thirty-five, one of the youngest recipients to date. To his own and everyone else's surprise, however, the Swedish pundits who chose the annual winners of the Nobel Prizes, awarded Guglielmo his jointly with Professor Karl Ferdinand Braun (1850-1918).

The year had not been a very propitious one thus far for Marconi, apart from his pride in the *Republic* rescues. His daughter Degna was a young baby, but he saw little of her, travelling endlessly, already drifting widely apart from his wife. During the summer he returned once more to America, leaving her behind in London. But when, after his departure, she found she was pregnant again, and hoping (as did her husband) that the child would be a boy, she impulsively dashed across to Ireland, boarded a pilot tug from Cork that was going out to meet his returning liner at sea. In her innocence she believed he would be delighted to see her, but in fact he was enjoying himself so much on board with his fellow-passengers, who included the singer Enrico Caruso and some attractive actresses, that an expectant Beatrice was the last person he expected or indeed wanted to see. Again there were tears and tantrums, and although he did shamefacedly apologise to his wife next morning, the rift between them was growing. As Degna said later, truthfully and without bitterness: "These were storms, violent and brief, of a sort that beset many marriages, but alas, these two proud, hot-tempered and quick-tongued people had more than the ordinary power to hurt each other and unusually tenacious memories to store up words spoken in anger."

However, things were patched up by December, when both husband and wife journeyed to Stockholm to receive his prize. When they arrived they found that Braun was as surprised as they had been over the joint award. However, he had worked on electricity and wireless at Strasbourg University, developing the cathode-ray tube and perfecting wave circuits, which are the basis of modern transmission. He had done research on directional transmission, and devised a method by which the power of the transmitting station could be increased at will. Nevertheless, he told Marconi that he felt the whole award should have gone to him. Before the presentation ceremony they talked together in friendly fashion, discussing scientific matters. The oddity of the situation was caught in a cartoon in a Swedish newspaper at the time which pictured both men, with Marconi saying quizzically: "I can't seem to place him," and Braun, with his neat beard and spectacles, bowing and protesting: "I am well known."

As well as the customary gold medal, diploma and the cash payment Marconi himself described later as "about £4,000," the recipients took tea at the Royal Palace with the Swedish Crown Prince and Princess, Gustaf Adolf and Margaret, and in her girlish way, Bea Marconi brought back an autographed souvenir of the occasion, with the signatures and photographs of Selma Lagerlöf, the authoress, who was awarded the Prize for Literature; Th. Kocher, W. Ostwald, Braun and her husband. In his particular field, Marconi was the first Italian to be honoured in this way, and his record was to last until 1938, when the prize was given to another Italian scientist, Enrico Fermi. When it was all over he set sail again, this time to promote business and undertake tests in South America. With him went another of his trusty lieutenants, H. J. Round, and this time they achieved easy results with signals from Clifden at a distance of 6,735 miles by night, and over 4,000 miles in daylight.

More lives were saved at sea by the use of wireless during 1910 and 1911, and in 1912 the first Cunard *Mauretania*, became the first merchant ship in which radio was used for direction and position-finding. When she crossed the Atlantic and back again in twelve days, despite unfavourable weather, she was able to report she had kept in touch with land stations the entire time. It is difficult to exaggerate Marconi's real joy in these nautical achievements: if his wireless had attained no other heights than these, he would have been well content. As well as the direct saving of lives and ships in emergencies, he had long been happily aware that through his work, there was secure hope of ending for ever that dread isolation from the rest of humanity that had been the inevitable lot of seafarers since the history of sea voyaging began. In April, 1911, the quiet announcement by a post-Marconi pioneer, Thorne Baker, created fresh interest in radio, and confirmed even more of Guglielmo's visionary dreams. Baker declared that music could be transmitted by wireless, and to prove it, he relayed through the ether between Brussels and Slough, of all places, some bars of "God Save the King."

In September, 1912, came an unexpected disaster in his personal life that was to tax Marconi's courage and endurance as never before. In spite of the birth of his son Giulio in 1910 (Beatrice Marconi did not know which ship her husband was travelling on in mid-Atlantic when the baby arrived, and she signalled the news addressed to *Marconi-Atlantic*, which was dutifully relayed from ship to ship until it reached him), relations with her were growing more tense each year, and they came close to parting. It did not help that the kind of lavishly gay entertaining she liked to do at their latest home, The Old Palace, Richmond, did not appeal to him at all, and merely annoyed him on the old grounds of extravagance and cause for jealousy. The final rift was only averted by the direct intervention of Annie Marconi, who took her daughter-in-law's side, and Guglielmo's friend Filippo Camperio, who finally persuaded him to make up and take his attractive wife on a motor tour through their beloved Italy.

Even then Marconi could not forget his role for a while. They had to visit Coltano, the country's first permanent wireless station, and entertain the King and Queen of Italy there. Bea had little Italian and even less French, which everyone seemed to be chattering in, and it hardly helped the situation when Queen Elena suddenly bestowed a rare honour upon Signora Marconi by appointing her a lady-in-waiting. On September 25th, they left Pisa for Genoa, with Guglielmo driving his big, brand new Fiat, Bea in the front passenger seat, and Bindoff, the family chauffeur, in the back seat. Marconi had been driving since about 1900 and was a good driver, fast, showy, yet safe, a demon of concentration as might be expected of him. He greatly disliked anyone talking to the driver on the road, saying, wisely, "A man can't do two things well at once." On this occasion, however, just outside Spezia en route for Genoa at 12.30 p.m., there was nothing he could do to avoid another car coming too fast towards him round a hairpin bend. He was building up speed to take the high curving road through the mountains, and inevitably the collision was a severe one. The occupants of the other car, which had overturned, were badly shaken, and at first it seemed that Beatrice and the chauffeur were worse hurt than Marconi himself. They escaped with serious bruising, Beatrice from the waist down, but Guglielmo sat quietly holding the steering-wheel, bleeding from his forehead and face. In reply to his wife's desperate enquiry, he answered with incredible calm: "I believe I've lost my eye."

He was rushed to the Naval Hospital at Spezia, where it was found that his temple and cheek had been terribly gashed, his right eye severely bruised and the eyeball pierced by a splinter of glass. The optic nerve was affected, and the surgeons were horrified to find that the sight of the undamaged eye was also failing. Dr. Baiardi of Turin, and Dr. Fuchs of Vienna, two noted eye surgeons of the day were hastily summoned to his bedside; they both agreed that the right eye must be removed to save the sight of the other. Marconi walked unaided into the operating theatre and endured the surgery without anaesthetic, merely groaning and never once complaining of the pain. Only when he was back in bed, heavily bandaged, did he declare: "I am not suffering any more, thank God." For a time, he was plunged into the deepest melancholy, fearing total blindness, chafing under the hospital restrictions, detesting the discomfort of swellings and dressings. Slowly but surely, the sight of the left eye returned to normal, and his fears evaporated. He got the celebrated Dr. Rubbi of Venice to make him a perfect glass eye. Many people in later years were quite unaware when they met him that he was a member of that staunch brotherhood who live with only one eye.

When World War I came in 1914 it was to bring with it enormous advances in the use of wireless, great developments—and a chance for Marconi to escape completely from his former life. At first, however, living at yet another new home, this time at Eaglehurst, Fawley, on the edge of the New Forest overlooking Southampton Water (bought on Camperio's advice as "a place in the country" designed to save their tottering marriage) they were treated with grave suspicion by the local folk. After all, Italy was a suspect country in 1914 owing to her alliance with Germany and Austria, and were the Marconis not obviously spies? local inhabitants argued. Had not Signor Marconi built a radio station inside one of the towers of the big house all ready to signal to U-boats out in the Channel? For some weeks they deemed it advisable to stay inside their high and extensive estate walls, but eventually, when the hysteria died down, Marconi set off on his globe-trotting once more, first to Italy, and then to America, where he still was when Italy entered the conflict on the side of the Allies in 1915.

He left immediately for his homeland and was at once accredited as an officer in charge of the country's military wireless system. Now he had the best excuse ever to be away from the family hearth indefinitely, wherever it might be. For the next three years, he travelled a great deal, visiting the Italian war front frequently, organising the manufacture and purchase of equipment for the Italian forces, making propaganda speeches on both sides of the Atlantic (he was at one time considered for the post of Italian ambassador to the USA), raising funds, sometimes popping into London to see his still growing family, occasionally "disappearing" completely from the public eye to get on with secret research or to fox the common enemy.

Wherever he went he continued his experimental work, and when he more or less settled in Rome in 1918, his house on top of the Janiculum Hill contained a top-floor laboratory that was the world's first one-man radio station. With his new large wire-frame directional aerial, he was able to pick up reports across the globe before anyone else in the country, and often passed them on to his government. Early in the conflict he had realised that naval and army signalling by wireless needed a secret, undetectable system, and he finally came to the conclusion that not longer and longer wireless waves were required, but the reverse. Before long, he was able to perfect short-wave radio sufficiently to make it usable in war, even to the extent of evolving direction-finders to spot enemy transmitters.

This was the first war to be fought with the aid of the ether, and in fact the warlike use of his invention began even before the official start of the struggle on August 4th, 1914. For on July 30th a signal from the British Admiralty ordered every ship of the Royal Navy to its war station, and likewise German stations warned German liners and merchant vessels, among them the *Kronprinzessin Cecilie*, leaving America with ten million dollars in gold on board, to seek safety in neutral ports. From then on all the nations involved used radio to the fullest possible extent, and there began for the first time the nowadays common-place practice of listening in to, or monitoring the transmissions of other countries. In 1915, two American companies successfully exploited the idea of the thermionic valve by building a transmitter equipped with hundreds of them wired together in "cascade" formation to produce continous waves. This made it possible for the U.S. naval radio station at Arlington, Virginia to communicate by voice with Honolulu, Hawaii, 5,000 miles away, while Paris, 3,700 miles away in the opposite direction "eavesdropped" on the conversation.

During the war years Marconi was inspired to make quite a few public prophesies that read interestingly today, and when this astonishing news reached him in Italy he declared: "There is not a shadow of doubt that wireless telephony across the Atlantic is assured in the future. . . . After the war a service will be installed. Europe will be within conversational distance of America . . . The time will come when a man may take up a telephone receiver in his London home or office, ask the central operator to connect him with New York, and do his talking without any more effort than if he were in conversation over a wire with Paris . . . The voice will be as clear and distinct as if those talking were not separated by the ocean." And a little later he said: "It may some day be practical to communicate with other planets. It's silly to say that other planets are uninhabited because they have no atmosphere or are so hot or are so different from the earth. If there were no fish in the sea we would say life there is impossible because it is infeasible for man. Presume there is life on Mars, a language barrier must be overcome . . . but I don't think it is insurmountable. You see, one might get through some such message as two plus two equals four and go on repeating it until an answer came back signifying 'yes', which would be one word. Mathematics must be the same throughout the physical universe. By sticking to mathematics over a number of years one might arrive at speech. It is certainly not beyond the realm of reason . . . By broadcasting a lantern slide showing a tree, an operator on earth, provided we can propagate the right wave lengths, could follow this picture with the word "tree" repeated many times in international code until the same dots and dashes were repeated by the distant planet. Then following this might be flashed the picture of a man with the caption "man" repeated. By this method language barriers might be surmounted and intelligent communication established."

It is noteworthy that both these ideas suggested by Marconi over forty-five years ago have quite recently been the subject of research and experiment by space scientists in America and elsewhere. Guglielmo quickly added at this interview: "But ask some of my material-minded friends, 'what is the practical advantage of all this; suppose communication is established?' I say the result would be the advancement of scientific knowledge by at least 200 years."

From now on Guglielmo was to dabble increasingly in Italian and world politics, encouraged by the Italian Prime Minister Nitti, and others. He found these incursions frustrating and disheartening. Attending the tragic Versailles Peace Conference in 1919, he was bitterly disappointed at the way Italy's claims were treated, and brooded deeply over the fate of the world: "I am grateful nature gave me a place in science instead of behind a counter. I often thought during the war of the romance of wireless. Messages came to me from Russia, Germany and Austria, intercepted dispatches, and they had come over the Alps, passed through hurricanes of artillery and made their way above all the beauties and miseries of the earth. Think of all those millions of words travelling with the speed of light above the earth, day and night carrying with them the destinies of the human race! The German talked and we caught his words out of the ether, and so with the Austrian, and the Bolshevik and everybody else. One sat listening to these words and all the time the world was in flames! It suggests the mystery of existence. It lifts thought to incredible heights."

Yet always elevated reminiscence gave way to despairing thoughts: "I am rather depressed at the condition of things. It seems to me very bad after such a war as this that a wave of brutality should be passing over Europe. It makes one not so much afraid as ashamed—ashamed of civilisation, of Europe, of human nature. People like to make out that the Russians are not Europeans, but they are. All this wave of brutality, rising in Russia, Christian Russia, is spreading westward. Think of all the people who are now stirring up disorder. I can't help hoping the League of Nations will save us. I am very much in favour of the League. I've met President Wilson and discussed his idea with him, but the rest of the world will have to help him if the League is really to exist. If this noble and grand idea fails, the next war will be infinitely more terrible than the last one. Civilians will certainly be much more implicated. Cities could be blotted clean out from the air—I hope men will soon turn their thoughts away from war."

Reading his words now, with after-knowledge, one can think of only one other Cassandra-like figure of world stature whose feelings, also publicly expressed, were the same, and whose words, like Cassandra's, went equally unheeded, that other Nobel prize-winner, Sir Winston Churchill. (Incidentally, in 1912, King George V had made the inventor an Honorary Knight Grand Cross of the Royal Victoria Order, rarely given to foreign nationals, which entitled him to call himself Sir Guglielmo Marconi. But loyalty to his own king decided him never to do so).

Yet tired, distraught and harassed as he was during these difficult years, Marconi never quite lost his dry sense of humour. When asked what he thought of the idea put forward by Sir Arthur Conan Doyle that wireless might be used to communicate directly with the spirit world, he replied with a grin: "I think it would take too long a wave-length."

In 1921 he came out with a world plan to ease economic ills, again one that has a familiar ring today. "Only a World Conference of Business Men Can Avoid Economic Ruin" declared one newspaper headline, quoting his panacea: "Let there be arranged a world conference of business men of proven ability in their own spheres of activity. Let each group have a mandate from its own government that will be authoritative and evidence that it has its government's full support. Out of such a conference, in my opinion, would come a practical, speedy solution of this pressing problem—surely the most urgently needed thing in the world today."

About this time the word "wireless" began very gradually to be superseded by the modern term "radio," derived from the waves that were "radiated;" but forward-thinking though he was in so many spheres, Guglielmo was still old-fashioned enough to cling to "wireless" to the end of his life.

He had certainly come a very long way since those early days in London in the 1890s, a way matured by terrible strains and agonies and suffering, of world adulation enjoyed by few men before him, of personal disharmony and disappointment, of humble beginnings that had led to still not completely discovered ends. Edward Marshall, an acquaintance who knew him in those early days in the Bayswater lodgings and who met him again in 1918, described those changes vividly: "The pale youth is now tall and of that firm, high-headed carriage which is given by conviction of success of real importance; but his manner is unobtrusive, almost shy, his voice is as gently modulated and his words are as modestly considered as they were when all the world was wondering whether he was maniac or genius . . . In the old days Marconi was unknown, or if known to any was regarded as a dreamer who possibly might have stumbled onto something big; but probably was merely in a mental mess. Then he was a supplicator at the doors of the powerful; now he is powerful in science and in . . . fighting for the freedom of the world."

Guglielmo Marconi knew what he had achieved scientifically. His great regret was that he was yet to achieve anything at all in the wider counsels of the world. "Everyone turns my ideas down bluntly," he complained. "They think of me as a mere scientist."

## Chapter 6

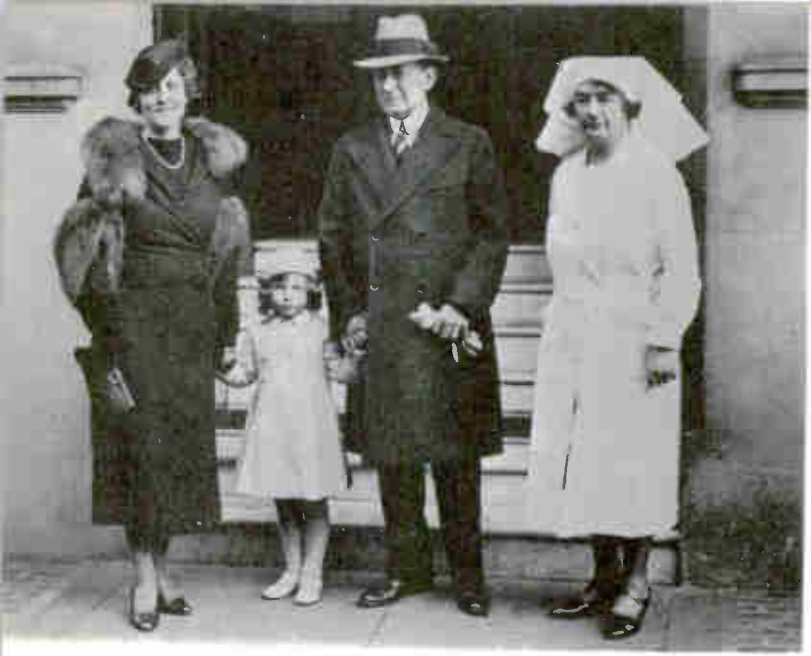
# LEARNING TO THE LAST

Yet Marconi's failure to play Hamlet on the stage of world affairs was matched by an equal inability to succeed on another level, if only he could have seen it—in personal relationships. There were many times now, and in the years that remained to him, when he seemed totally insensitive to the feelings and needs of those close to him. He seemed to expect from his family and intimates the same blind, unquestioning loyalty he always received from his assistants and working associates. They had the incentive of the new invention, and of commercial success, of course, but Guglielmo never was able to see any difference between the two types of relationship. As always his relationships with women were superficial, glossy, brittle, and usually brief, although he did have one more serious affair just after the war with a mystery woman Degna Marconi describes as "beautiful, Paris-chic, and cunning." Bea Marconi had long since sacrificed the pride in the cause of her marriage, condoning his many infidelities, knowing that when each affair ended he would come back contritely as if nothing had changed. Impervious as ever to his wife's emotions, he steered his way out of each upset by mooching off to experiment further with radio-telephony.

In the end Beatrice not unnaturally decided she preferred the attentions of her next-door neighbour in Naples, the kindly Marchese Liborio Marignoli. In 1923 she asked Guglielmo for a divorce, and he, characteristically, was shocked and surprised. Bea and Marignoli married soon after, and for a time, Guglielmo erased all these inconvenient thoughts from his incredibly detached mind. He continued to see his children, for he was always a kindly, if spasmodically attentive father, and for a while, he was generous, too. But all this was to change. In 1925, this brilliant yet oddly immature man wrote one of his still affectionate letters to his former wife (he always addressed her as "Dearest B.") telling her he intended to marry Betty Paynter, a girl of seventeen, for whom he said he cared "an awful lot, more than I ever thought I could... I have been fighting against myself over this for a long time, but I am afraid it's no use." He was fifty-one, as superficial in his relationships with women as ever, though he really believed otherwise. Beatrice Marignoli flashed back her Irish indignation in a way that must have made him blink. She wrote: "I am surprised to hear you have decided to take the step you write me of in your last letter and create new ties and most probably a new family. I would like to wish you every happiness but this news distresses me for I wonder after all the years we were together when your own desire expressed continually was for freedom to concentrate on your work as your family impeded and oppressed you, why you should suddenly feel this great loneliness and need of a home—this craving for fresh ties!" They met and discussed the matter, and when she asked him why he wanted to talk it over with her, of all people, he replied: "Because you are the only person in the world who will tell me the truth."

This abortive romance fizzled out, but his acute loneliness that ran parallel with his intense need for solitude he assuaged once again with "fly-by-night ladies" who could bring him no lasting happiness. Then, in the spring of 1925 he met the twenty-six-year-old Countess Maria Cristina Bezzi-Scali, daughter of a Vatican nobleman, a member of the Pope's Noble Guard, and his equally aristocratic Roman wife. Once again, now aged fifty-two, he was entranced with feminine youth, beauty, simplicity and lack of sophistication. Cristina Bezzi-Scali was a striking, tall girl, with fair hair and large blue eyes, quiet, demure even, even more unworldly than Bea had been. Once more he fell headlong, and this time he knew that she must be his new bride.

17-18 Marconi, with his wife and friends, on board the *Elettra* in 1934. In spite of illness he travelled widely during this period and often appeared as a public figure, as at the opening of Radio Tupi, in Rio de Janeiro in 1935.



19-20 Marconi leaves a nursing home in 1934, accompanied by his wife and daughter Elettra. Illness was to haunt him until his death in Rome in 1937. After his death the Mausoleum shown here was erected in his honour in the grounds of the Villa Grifone in northern Italy, where Marconi carried out his first experiments.

But full of his own blind spots as ever, he bargained without the power of the Roman Catholic Church. As a divorced man he could never expect to marry a girl whose father was so prominent in the Church. Nevertheless, once Guglielmo had made up his mind about a thing, he was usually determined to move Heaven and earth to get it. To this end he consulted lawyers to see if he could satisfy the strict ecclesiastical authorities sufficiently for them to grant an annulment of his first marriage on the grounds of "lack of consent." This devious course needed proof that the first union "had been entered into with mental reservations by either or both of the contracting parties." Naturally this would require confirmatory statements from Beatrice, and he had no compunction in using threats to get her to do something she was already quite willing to do to further his own happiness. Other witnesses also had to be cajoled into giving the evidence required by the sacred courts in Rome and London.

It was an unsavoury episode to say the least, especially for Beatrice herself, a Protestant divorced woman married under civil, not religious law to a Catholic in a Catholic country and having borne him a daughter, but Guglielmo as usual spared no one's feelings. The pathetic, tortuous letters he sent to "Dearest B." through the year 1926, with their detailed underlined demands and instructions as to what she should say when questioned, represent the least praiseworthy period of Marconi's whole life, and when read today as between two people who were married for some twenty years and who had four children, are certainly extraordinary. However, events moved painfully in his favour, and on April 27th, 1927, the Sacra Rota Ecclesiastica of the Roman Church annulled their marriage on the grounds of lack of consent. How Bea must have recalled Queen Elena of Italy's words when she went to see her before their divorce to resign as a royal lady-in-waiting and return her diamond badge of office: "A man like Marconi should never marry."

Guglielmo married Cristina Bezzi-Scali shortly afterwards and they had a rapturous honeymoon in Italy and America, where, on his 85th visit, the Italian celebrity was greeted rapturously and Michael Pupin declared at a reception: "Marconi, we love you. We have come to see your boyish smile as much as to hear what you have to say."

The boyish smile may have endured, but soon the trim figured thickened, the hair greyed and had to be dyed at the temples and the lean charm gave way to something rather less attractive. There were other unattractive aspects of the man, too. In New York on this occasion in 1927, he posed beaming before the cameras wearing a blue suit, white shirt with purple stripes, purple tie, purple socks, brown shoes—and in his lapel the red, green and gold emblem of the Italian Fascisti. Mussolini was already in power in Italy, and to reporters, Marconi declared: "Fascism is doing fine work in Italy. Italy, under Benito Mussolini, has turned the corner. His bold, audacious political and financial policies have transformed the country." He spoke, too, of the dictator's "genial leadership." So after all, Guglielmo Marconi was a political innocent.

Originally, there is no doubt he sincerely believed in Mussolini's power to save his country, but he was too naive at first to recognise that in time he was being used by the Fascist regime for its own ends. Mussolini visited his laboratories on several occasions, showing a great interest in his continuing research work, in unforgettable contrast to the earlier rulers of Italy. For a time the dictator cultivated him as a personal intimate, asking his advice on world, and especially British and American affairs, listening to his comments as no other world leader had ever done.

Then came the testing period of the Abyssinian war in 1935, but for a while Marconi's faith remained unshattered. After all, King Umberto stayed on, so why should not he? he reasoned. At one point, grieved by British hostility to the revolting Abyssinian compaign, he sought to broadcast on the B.B.C. an "unbiased" explanation of the need for it, to explain to the country of his adoption why the country of his birth was acting in this aggressive way. He was, ironically enough in the circumstances, refused air time, although his own supporter, *The Times*, stood by him in his request. Part of the trouble lay in Marconi's inability to endure the sneers of "patriotic" influential Italians who had already climbed on to the Fascist bandwagon that he was "pro-British." That stung his own genuine patriotism very deeply.

A degree of disillusionment was to come, however. By 1936 he came to realise all was not well with his country and its rulers. One day he told his eldest daughter that it was useless even to try to talk to the Duce any longer. "He will listen only to what he wants to hear." If Marconi had lived a little longer, the disillusionment would have been greater and he would have learned that all dictators get to that stage, Adolf Hitler most of all.

Of this last phase of Marconi's life the key event is undoubtedly his acquisition of his famous ocean-going yacht, the *Elettra*. "I was born to be a sailor," he said once. "I never feel as well as when I am at sea. I like the sea because not only does it take me away from all troubles on land, but because at sea I can meditate, study, and experiment at my will."

He bought the vessel, a beautiful steam yacht, 220 ft. long, of 730 tons displacement, with a high prow and truly rakish lines in her tall funnel and twin masts, in 1920. She was Scottish built, and was completed in 1904 for the Archduchess Maria Theresa of Austria, who called her the *Rovenska*, and although already finely appointed, she was completely refitted and equipped as the most wonderful floating radio laboratory in the world, either before or since.

From about 1922 until the end of his life, Guglielmo spent every minute he could on board her, sailing all over the oceans, escaping from the worries of money, commerce, politics and marriage, and doing on her almost all his vitally important postwar experimental work. He never tired of talking about the *Elettra*, either, declaring on one occasion: "The yacht not only makes me independent but it takes me away from curious eyes and distractions. I can work there at all hours of the day and night, finding without delay suitable grounds for all kinds of experiments which would be difficult to carry out on land."

With her crack skipper, Captain Lauro, formerly of the Italian Navy, and her hand-picked crew of thirty-one, the *Elettra* undoubtedly represents the deepest happiness Marconi was to enjoy after the end of World War I. His great friend, the Italian visionary poet

Gabriele D'Annunzio, called the sleek, fast white vessel "the shining ship that works miracles, penetrating the silences of the air." Her relaxing effect on the man also undoubtedly prolonged his life to enable him to do his last, forward-looking work on ultra short waves, leading to the beginnings of television. For the warning signs of his failing body first appeared on his return from his honeymoon trip to America with Cristina in 1927, when in London that winter he suffered his first attack of angina. Now a Roman Catholic himself, he began to see that perhaps life could not be taken for granted as he imagined, and he had to slow up considerably. In fact, he was not able to return to active radio work until 1930. But the *Elettra* was still his, and on her spotless bridge and decks he convalesced happily; in his white suit and black-peaked, white-topped yachting cap, with his young bride at his side, he was a familiar figure in a dozen ports, Genoa, Naples, Monte Carlo, Cowes, New York, Bermuda, Beirut, Venice and Southampton among them.

The work he did aboard his yacht was to be his last great work, but it was second in importance only to his early pioneering efforts. On one of his very first trips on her in 1920 he started the first of his many experiments on long-range radio, and whilst crossing the Bay of Biscay his guests in the stateroom danced to the music of the Savoy Orpheans jazz band playing in London, and when in mid-Atlantic they listened to Melba singing at Covent Garden. Her voice was simultaneously re-broadcast by *Elettra's* equipment to other stations in Europe. These were staggering feats at the time. By 1930, the yacht's apparatus was the most sophisticated in the world, and Marconi several times broadcast from her whilst at sea. He never lost his great flair for publicity, and on March 26th, 1930, by depressing a key in the *Elettra's* radio cabin he closed a radio circuit over 9,000 miles away in Sydney, causing 3,000 electric lights to flash on to open an Electric and Radio Exhibition there. Most of his work at sea concentrated on the use of ever shorter radio waves for both radio telephony and general broadcasting: the problems of this, and of transmitting not merely lantern slides but moving pictures in the form of television, occupied most of his working thoughts right up to the end.

By about 1931 he was working with waves not measured in metres, or even miles, as they had once been, but in mere centimetres. He knew that the ultra-short wave and the microwave held the key to the real future of radio as a world force. He equipped the Vatican radio station with a powerful short-wave transmitter as early as 1931. "With the help of Almighty God," said the convert, "who places such mysterious forces of nature at mankind's disposal, I have been able to prepare the instrument that will give to the faithful throughout the world the consolation of hearing the voice of the Holy Father." Again in 1933, he linked by microwave the Vatican in Rome with the Pope's summer residence fifteen miles outside the city at Castel Gandolfo. At the microphone, Pope Pius XI declared: "Our first word shall be for you, Marchese Marconi, and it will be a word of congratulation for the continuous success that Divine Providence and Divine Goodness have reserved for your researches and applications in this field." Guglielmo replied: "This first application of microwaves fills my heart both as an Italian and a scientist with hope and pride for the future. May my modest work contribute to the achievement of true Christian peace throughout the world," and one cannot doubt but that he was devoutly sincere in both speeches.

Although he had been a *Senatore* (Senator) of Italy since 1914, his greatest honour from his native land was not bestowed upon him until 1929, when the King of Italy gave him the hereditary title of *Marchese* (Marquis), by which he was usually known to the end of his life. This made Cristina *Marchesa* (Marchioness) Marconi. Modest as he was, there is no doubt at all that he was especially proud of this title, with the special aura of distinction it carried. In 1930, his young wife presented him with yet another daughter, whom he named Maria Elettra Elena Anna. The girl was called Elettra, after his yacht, and after some years of financial upset and stinginess, resulting in the withdrawal of his former allowances for his other family, they and Beatrice were shocked to learn in due course that his will, dated 1935, left everything to Cristina and Elettra. For many years now he had been increasingly extravagant in matters of personal expenditure, yet at long last his commercial financial background was secure beyond all earlier hopes.

For some years after his first heart trouble, Marconi, his wife and baby, and various friends from the international set travelled widely, but the heart attacks gradually increased in frequency and severity, and Cristina spent a lot of time getting him in and out of nursing-homes. In the last phase of his life he seemed to glory in personal publicity, posing endlessly for photographs and newsreels, appearing at various public ceremonies and so on. Perhaps he felt his chances of glory were vanishing fast. He aged quickly in the final years, his face becoming unpleasantly puckered, his manner verging on dotage. From time to time, however, he regained his former wisdom and vigour, as when he celebrated the thirtieth anniversary of the first Atlantic transmission in 1901, and stood proudly with dear old Kemp and Paget in the Company's London office at a special ceremony, after which he broadcast to the world, his words going out from England in the biggest radio hook-up ever attempted, linking London with New York, Ottawa, Rio de Janeiro, Caracas, Honolulu, Berlin, Rome, Paris, Warsaw and Brussels. Pupin spoke from America, comparing him with Italy's other great scientific son, Galileo, and Lord Rutherford presented him with the Kelvin Medal. For George Kemp it was the happiest day of his long life spent in the cause of wireless and his Chief: a few weeks later he was dead.

Occasionally, too, he came out with some words that were worth recording, like these set down by Orrin Dunlap: "The messages wirelessed ten years ago have not reached some of the nearest stars. When they arrive there, why should they stop? It is like the attempt to express one-third as a decimal fraction: you can go on for ever and ever without coming to any sign of the end. What is jolly about science is this: it encourages one to go on dreaming. Science demands a flexible mind. It's no use interrogating the universe with a formula. You've got to observe it, take what it gives you and then reflect upon it with the aid of science and reason. Science keeps one young.

I cannot understand the savant who grows bowed and yellow in a workroom. I like to be out in the open looking at the universe, asking it questions, letting the mystery of it soak into the mind, admiring the beauty of it all, and then think my way to the truth of things." Or talking to Degna Marconi on one of their now rare meetings: "Do you hear them talking of genius? There is no such thing. Genius, if you like to call it that, is the gift of work continuously applied. That's all it is, as I have proved for myself. I'll tell you, if you set your heart and soul in a thing you can do it."

Perhaps the real key to this oddly likable yet baffling man is simply that: hard work, determination and a refusal to accept anything as impossible. All his life he thoroughly enjoyed proving the "experts" wrong. In a gleeful speech to the Royal Institution in London, Faraday's old home, in 1932, he pointed out to his learned audience that very short waves were generally believed by scientists to be useful for radio communication only "when the transmitter and receiver are within visual range of each other." "Long experience has, however, taught me not always to believe in the limitation indicated by purely theoretical considerations or even by calculations. These, as we well know, are often based on insufficient knowledge of all the relevant factors. I believe, in spite of adverse forecasts, in trying out new lines of research however unpromising they may seem at first sight."

Certainly the lesson of his whole life is his total and continuous refusal to take "No" for an answer, no matter from whence it came—Giuseppe, Righi, Kelvin, Lodge, the cable men, governments everywhere, the long-wave adherents, the scoffers and doubters, even the Vatican and Queen Victoria! Quite apart from his basic achievements, therein must lie his lesson for posterity.

Guglielmo Marconi suffered three minor heart attacks in the spring of 1937, grieved that his faithful brother Alfonso had lately died of the same heart disease he was fighting. He was a sick and tired man, confined now to his grand house in Rome, his travelling days over, yet he was not un-mellow, and he still delighted in the news of continuing wireless developments that Luigi Solari brought him from time to time, especially in the field of microwaves. "There is still much to be learned, Solari," he said one day, "and I am preparing to learn it." His doctors tried not very successfully to make him live the life of an invalid. In July his health worsened, and the end came, quite peacefully, in the early hours of July 20th, 1937. He retained his questing, scientific mind to the very last, and was puzzled as to why the pulsation of blood in the artery of his arm had ceased yet his heart continued to beat.

"How is it, Frugoni," he asked his doctor, "that my heart has stopped beating and I am still alive?" The doctor replied: "Don't ask such questions, it is only a matter of position, because your forearm is raised." Marconi gave a little wry smile and said: "No, my dear doctor, this would be correct for the veins but not for an artery. But I don't care, I don't care at all . . ." They were his last words.

Quite soon, as was most fitting, the news of the death of the father of radio crackled and clicked through the ether to and from a myriad stations, was passed on by countless radio operators. "The Chief," "The Marchese," "The Old Man," "Mr. Marconi," "G. M." —by whatever name they knew him—was no more. The legend had vanished; only his endlessly throbbing memorial, annihilating space and time, destined to make the world one if anything could, remained. At 6 p.m. that evening, led by all B.B.C. and G.P.O. transmitters in Britain, radio stations in many countries across the world went off the air for two minutes' commemorative and significant silence, operators stood with bowed heads beside their apparatus in tribute. It really was a significant silence, for to this strange, "pale, calm, kind, meticulous" man, more than any other, was owed the lifting of the awful silence that had separated men since the beginnings of the human race.

# PART II

## Chapter 7

# FROM PONTECCHIO TO POLDHU

The "wireless waves" that Marconi set to work so successfully are of course a natural phenomenon, yet they first attracted attention less than 150 years ago. They are only one form of electro-magnetic waves that travel through space. They have the longest wave-lengths and therefore the lowest frequencies in the electro-magnetic spectrum. The others, in order of increasing frequency and therefore decreasing wavelength, we call infra-red or invisible heat waves, visible light waves, ultra-violet waves, X-rays and cosmic rays such as gamma rays. All forms of electro-magnetic waves travel at a fixed speed through space. This has been accurately determined as 299,790,000 metres per second, or for more practical purposes, very nearly 300 million metres per second—usually given as 186,000 miles per second, and commonly known as the "speed of light."

*Real waves* can move only through water (as in the sea), or in some other liquid. Sound waves consist of compressions in the air or other gases, and so require such a medium to carry them. But electro-magnetic waves, consisting of waves of electrical energy, can travel freely through air or space without relying upon any such medium to support them. This is clearly proved every time we look up at the stars, which send their visible light waves to us over colossal distances without requiring any material medium in between.

The way in which wireless or radio waves came to be thought of in the minds of Marconi and the pioneers who preceded him as a possible communicating medium themselves is naturally linked with the development of the science of electricity itself. That there is a firm connection between the flow of electricity in a wire and the static condition known as magnetism was demonstrated as early as 1820 by the Danish scientist Hans Christian Oersted. The principle was developed further in France and England and Michael Faraday proved the reverse—that is that current can be set up in a dead wire by moving a magnet near it—some eleven years later. This principle of induced electric current formed the basis of generating electricity and from Faraday's earlier work stemmed the principle of the condenser coil so useful to Marconi and others. Faraday also was the first to suggest that some form of vibration was involved in the action of electricity and magnetism, an idea obviously very close to our more modern concept of waves. The brilliant young Scottish scientist James Clerk Maxwell took it up and developed the theory authoritatively twenty years before Hertz finally proved the existence and behaviour of electro-magnetic waves in the laboratory. Hertz also proved that such waves could be transmitted, reflected, diverted, refracted and even polarised in the same way as light waves —the whole basis of wireless transmission and reception. In other words, it was perfectly possible to send out electrical energy without having to send out the current itself, thus eliminating the need for connecting wires. It was the transmitted energy which did the work at the receiving end, always provided enough energy could be sent.

A simple analogy is provided by a vertical stick in a calm pond. If the stick is pushed gently into the centre of the water, the level of the water will rise very slightly over the whole surface; the only energy created would be that required to force the stick upwards out of the water if it were let go. On the other hand if the stick is pushed in and out of the water waves are created which radiate outwards in all directions; they carry energy away from the moving stick and this energy is finally spent forcing the water up and down at the edge of the pond. The energy is carried by the waves without moving the water itself towards the edge. If the stick is raised and lowered at a definite rate each wave spreads outwards at a fixed speed and each wave follows at the same distance from the one before it. The measurement from crest to crest is the "wavelength" and the number of waves leaving the stick each second the "frequency."

In terms of wireless the stick becomes the transmitting aerial, the pond water the "ether" and the waves of water become electro-magnetic waves. If a steady current is supplied up the vertical wire of the aerial to the top, or antenna, this will be electrically charged but its electrical field would be weaker the further one moved away from it (the stick held steady in the pond). But when the current from the transmitter fed up the aerial wire to the antenna is alternating at high frequency (the stick pushed up and down in the pond), the result is very different. The current surges up the vertical wire, charging the top, then quickly flows down again, discharging the antenna and charging it up again with the opposite flow of electricity. As in the water the changes in the flow are reflected outwards through the waves at a regular rate and these are felt at a much greater distance than the effect of a steady electrical charge. Electrical energy travels outwards from the antenna in the form of waves which radiate continually until their source of energy is spent at a distance, just as the waves from the stick finally peter out. The more vigorously the stick is moved, and the higher its vertical speed, the wider and longer the effect. So it is with the power and frequency of a radio transmitting aerial. For in the pond, the stick has to be moved up and down fairly rapidly before the first wave it starts has gone very far, otherwise much of the effect is lost and the resulting waves very feeble indeed. The same effect holds good for radio waves. To be of manageable length, and to travel any useful distance, they must operate at very high frequencies. One rule applies to all waves, whether in the water or in space: their energy is greater the shorter their time of swing, that is, their wave-length. To illustrate this point: the fixed frequency of the ordinary mains electricity supplied in Britain and many other countries is fifty cycles per second. Although this can readily be converted via a loudspeaker into sound waves of the same frequency—the familiar, low-pitched "mains hum"—this alternating frequency is so slow that it gives a wave-length of six million metres, about 3,740 miles, and its radiation of electrical energy so feeble that it can only be detected very close to its source, if at all. To get, say, a 300-metre wave-length an alternating frequency of one million times a second is required, for a 100-metre wave, three million cycles per second, and so on.

To change the analogy, a broadcasting station today may be like a lighthouse, sending out its continuous "rays" or invisible waves, either radiating in all directions like the ripples on the pond, or else directed in fixed directions along beams. All radio waves are much akin to light waves, in fact, although they operate at much lower frequencies and so are always invisible. The higher their frequency, that is the shorter their wave-length, the more they approach light waves in their characteristics, and the easier they can be directed along narrow beams.

Hertz quickly realised the importance of his discovery. He managed to measure both the length and the frequency of the waves he produced, showing that in many respects they were similar to the waves of light and heat. He felt that the waves, soon to become known as Hertzian waves, must travel in some mysterious, all-pervading, weightless, non-material, air-less medium, which was necessary to support electro-magnetic wave-radiation. When Lord Kelvin came to translate Hertz's account of his discoveries into English, he termed the waves "ether-waves," and so they were believed to move in the "ether" (or "aether"). Modern scientists are of the opinion that this notion of the romantic-sounding ether is altogether too unsophisticated for reality; they claimed that since a fixed ether is not observable anywhere, the term must have only a very limited usefulness. To Marconi, and all the other wireless pioneers, however, the ether, carrying their precious signal-waves, had a very definite existence.

David Edward Hughes, Hertz, Branly and others produced devices that would react to the existence of these waves, record their movements (they were actually ultra-short waves, with a length of only about one inch in Hertz' case) and their velocity. The most sophisticated were devised by Branly and, working independently, Sir Oliver Lodge, which worked on the principle that metal filings in a thin glass tube temporarily stuck together or "cohered" when they sensed incoming electromagnetic waves and so completed a circuit through which a local electric current could pass. Once the filings were vibrated mechanically, however, they separated again and the flow of current was broken. So a mechanical tapping device fitted at the end of the tube could cause the filings to decohere at the end of each impulse received and thus permit the signals from the transmitting end to be deciphered accurately. This "coherer" was an extremely primitive piece of wireless apparatus, yet it was important at the time and widely used, often being made to operate a bell or relay switch direct. It was soon superseded by Marconi's own magnetic detector.

Nonetheless, Marconi's very earliest apparatus would be considered terribly crude by any schoolboy of today. Like Hertz, he used two ball electrodes, and to get a spark across them he had to use induction coils. These consisted of a primary tight winding of fine wire over a soft iron core, with a secondary winding twisted over the first. By intermittently interrupting a low-voltage current from a Leyden jar battery flowing through the primary wire, thus making use of Faraday's discovery, a much higher voltage was induced in the secondary coil and this leapt readily across the spark gap between the two balls and so radiated the necessary waves for transmission. As seen by Daisy Prescott, Marconi sent his earliest impulses across the attic room at the Villa Grifone by means of curved zinc reflectors. For aerial he used a thin copper sheet about two feet square, suspending it vertically in the air from wires or bamboo poles. There was a tapper key to transmit the regulated impulses, and the simple coherer to pick them up at the other end—originally, as we have seen, just across the room. It was the coherer that worked the bell Annie Marconi was dragged out of bed to hear.

This basic spark transmitter was to hold sway for a considerable time. In Marconi's very first work, the spark was sufficient in itself for its effect on the ether to be felt by a sufficiently sensitive receiver a few yards away, but its strength as a source of wireless signals was enormously increased if one of the balls at the spark gap was connected by means of a vertical insulated wire to a primitive aerial, and the other to a metal plate placed on or in the earth—the "earth-plate." It is this bold use of the aerial-to-earth circuit that was the outstanding innovation of Marconi's original system, for it extended the potential range of transmission. By completing the overall circuit by means of the earth itself, the range became in effect limited only by the power of the transmitter and the range of the aerial used. Originally a copper sheet, the aerial was soon changed to a metal cylinder hoisted on to a mast. Gradually, the aerial became a simple wire line, held aloft by tall poles, ships' masts, balloons or kites. Finally, it grew into what it is largely now, a system of wire lines held aloft by steel pylons.

Marconi's own account of his first major experiment at Pontecchio, written in reflection long afterwards, is interesting: "I reproduced with rather rudimentary means an oscillator similar to that used by Righi; I likewise reproduced a resonator using as a detector of the electrical waves a tube of glass with pulverised metal based on much that was already published by Hughes, Branly and Lodge. By means of slabs of curved zinc, I formed two reflectors which I placed one in front of the other at the maximum height permitted by my laboratory. At the centre of the far room I put the detector of the electric waves and bound this to a battery." This link-up worked sufficiently well to ring the bell on that fateful night. But the coherer based on Branly's design worked erratically. The operator himself had to free the metal particles after each impulse by tapping the glass tube himself. Also, the filings of copper, iron, brass or zinc that Branly and other workers concluded responded best to sudden increases in conductivity proved unreliable. Marconi decided on a mixture of 95 per cent. nickel and 5 per cent. silver dust, and reduced the glass tube in size until it closely resembled a clinical thermometer. He narrowed the slit in which the particles rested, and removed the air from the tube. The vacuum coherer worked far better, but there still remained the problem of de-cohering. "To shake the metal filings automatically I inserted a loadstone (magnet) in the origin of the voltmeter circuit. This commanded a little clapper, placed where it could serve as a contact with the tube containing the filings. Every time I sent a train of electric waves, the clapper touched the tube and so restored the detector at once to its pristine state of sensibility. It was precisely at this moment that I thought for the first time of transmitting telegraphic signals and of substituting a Morse machine for the voltmeter. The extremely weak current available with my materials was insufficient to make a Morse machine function. I at once thought of reïnforcing the current with a relay. And this I did later. For the present it seemed to me necessary above everything else to study the behaviour of electric waves at an increased distance outdoors, outside the limited space of my laboratory. I had complete faith in the possibility. With this in mind I went to consult Professor Righi, who expressed grave doubts as to the practicality of my project. And indeed he was right, *senza presa di terra* (without the grasp of the earth). In my first experiments outdoors towards the end of September, 1895, I considered increasing the dimensions of the transmitter in order to get waves longer than any that had been used up to that time—waves 30 or 40 metres long. With this in view, I replaced the two outside balls of the Righi oscillator (there were four) with two slabs of sheet iron I got by breaking up an old tank. I did the same thing to the resonator. I found out then how to obtain waves at distances of hundreds of metres. By chance I held one of the metal slabs at a considerable height above the ground and set the other on the earth.

"With this arrangement the signals became so strong that they permitted me to increase the sending distance to a kilometre. That was when I first saw a great new way open before me. Not a triumph. Triumph was far distant. But I understood in that moment that I was on a good road. My invention had taken life. I had made an important discovery.

"Next I thought of substituting copper wires for the slab that I had suspended in the air. These I separated from one another by wooden spokes. The slab on the ground I replaced with a piece of copper, buried in the earth. Once more the effect was impressive. The invention of the antenna-terra (aerial-to-earth) had been made. But I knew my invention would have no importance unless it could make communication possible across natural obstacles like hills and mountains."

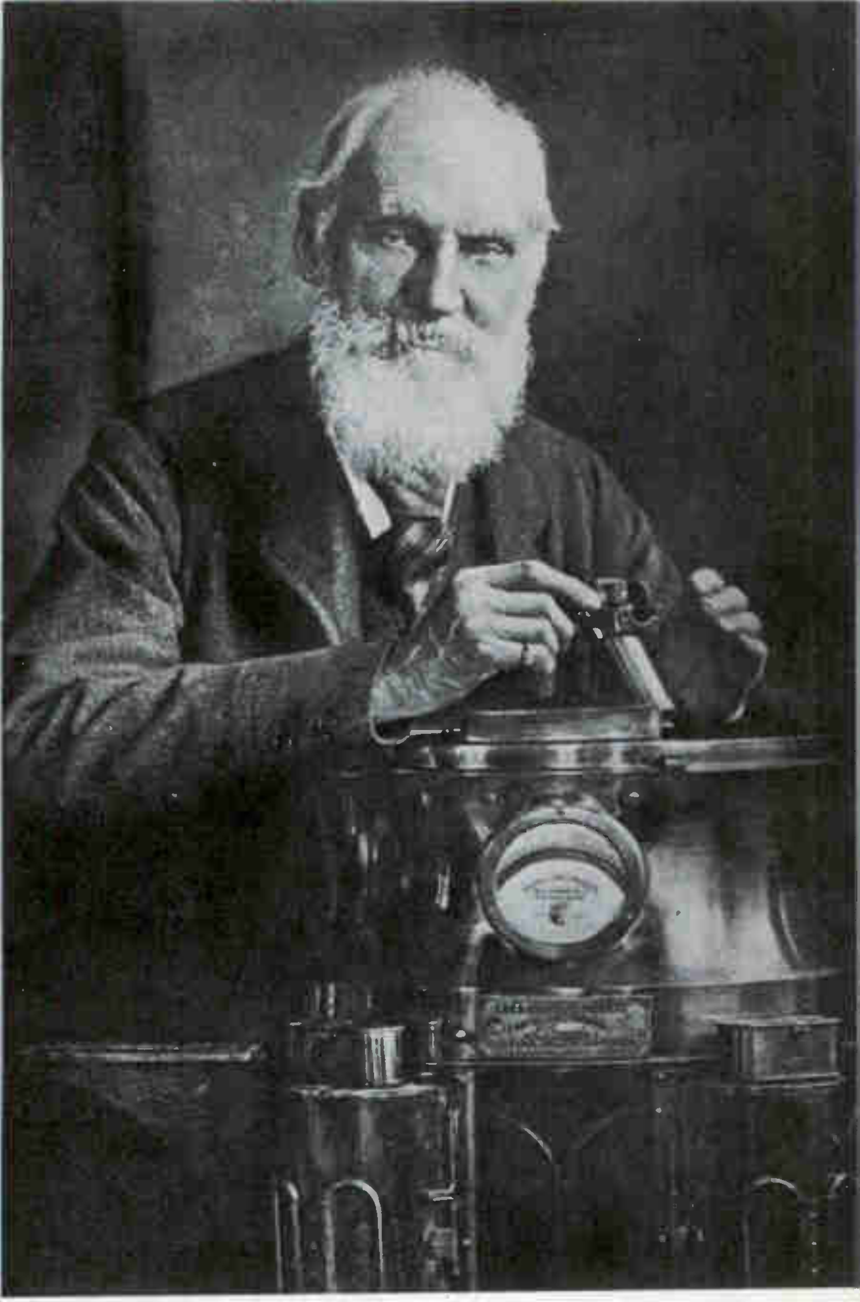
Interviewed two years later in London by a reporter from the New York *World*, Marconi illustrated this further: "My discovery was not the result of long hours and logical thought, but of experiments with machines invented by other men to which I applied certain improvements. I used the Hertzian radiator and the Branly coherer. The radiator was what would be known in telegraphers' speech as the sender, and the coherer the receiver. Before I began the experiments these two instruments would send a message without wires a distance of from 30 to 300 yards, but there the power ended. The improvements which I made were to connect both receiver and sender with first the earth and second the vertical wire insulated from the earth . . . At once instead of being limited to a few yards in results, I extended the distance over which a message could be sent to about two miles. I found this principally due to the vertical wire, and speaking as simply as possible, I believe the following theory may explain why this was so.

"Everybody knows how sound is transmitted by means of vibrations of air. For instance, if you fire a cannon, the concussion produced by the explosion of the powder causes the air to vibrate, and so far as these vibrations of air extend, just so far is sound audible. In other words, sound consists of vibrations of air. Well, my vertical wire carries the electric vibrations up into the air and produces certain vibrations in the ether, and these vibrations extend in every direction until they reach the receiving instrument. Thus a message can be transmitted through the ether for as great a distance as you can cause vibrations to proceed. The original Hertz radiator worked on the same principle, but the vibrations its two brass spheres produced were very slight. My improvement magnifies them.

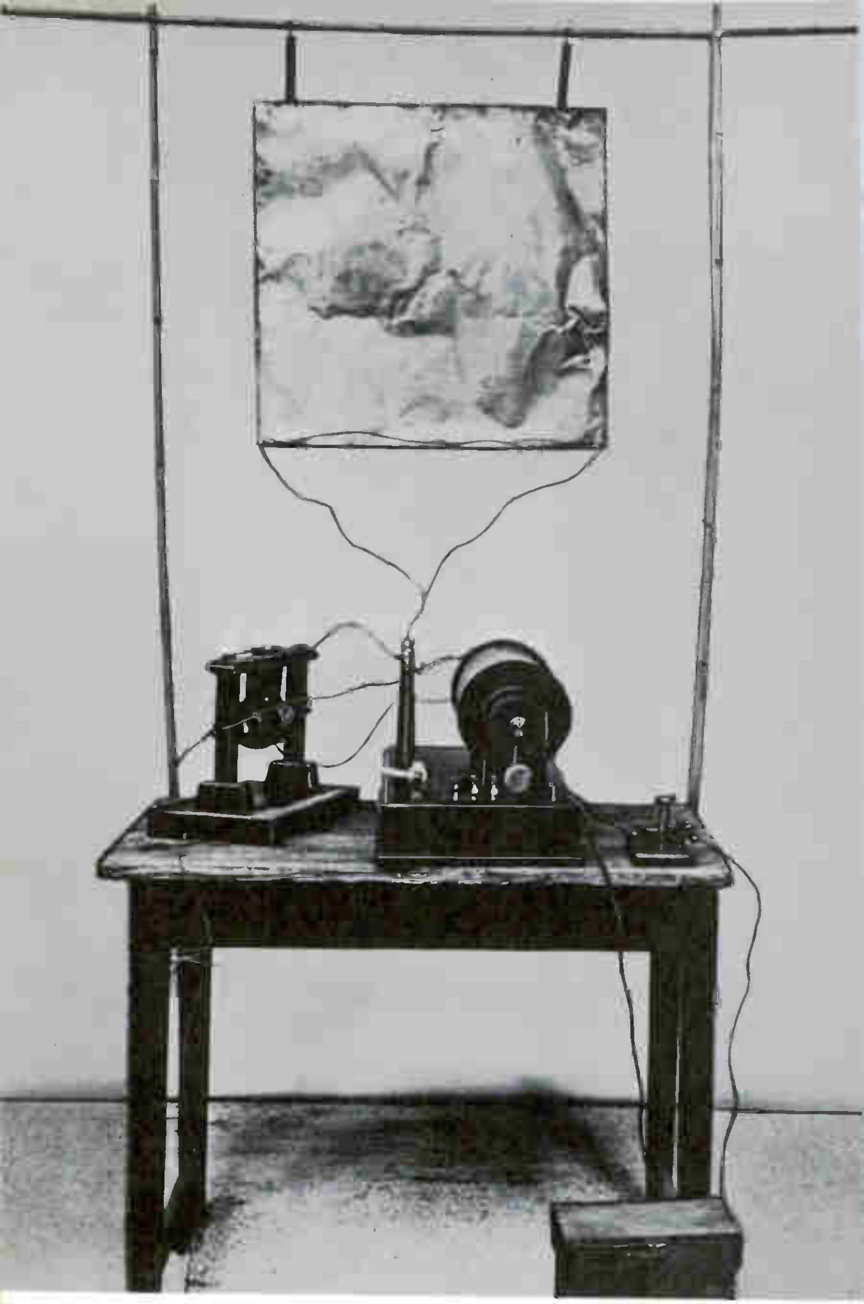
"An Italian scientist in speaking of the case said: 'The old Hertz radiator and old Branly coherer might be likened to the reed of an organ. By the Marconi improvements the pipe of the organ is added. The reed would make very little noise, but when you add the reverberant power of the pipe you get a great volume of sound. Marconi's connection of both receiver and transmitter, first with earth, second with air, supplies the pipe to the reed and makes the volume of vibrations great enough so that it will reach great distances.'

"As a matter of fact before I improved the receiver, it was impossible to end one pole of the transmitter with the earth and the opposite pole with insulated vertical wire. It was impossible to communicate intelligible messages even thirty yards, but after I had done these things, I succeeded in communicating from the Arsenal of San Bartolomeo at Spezia with an ironclad (the San Martino) twelve miles away on the water. I have no reason to suppose that this is the limit of the possibilities of the system. Indeed, I am sure that it is not the limit . . ."

Soon after Marconi arrived in England in 1896 he posed in his London lodgings for the famous photograph showing the notorious "black box" and its contents on a table. This of course was the replacement transmitter, built in England, not the original one brought from Italy, but it shows quite clearly the crudity and simplicity of the equipment with which he hoped to impress the G.P.O. On the left of the photograph stands a little frame supporting a small induction coil above two of the large ball electrodes, partly hidden behind the curved metal reflector. The tapper key is mounted on top of the box itself, on the right.



21 Lord Kelvin, the famous British scientist, who was in his seventies when Marconi began his experiments in England. At first he scoffed at Marconi's invention: "Wireless is all very well, but I'd rather send a message by a boy on a pony." But later he became one of Marconi's strongest backers.



22 A replica of Marconi's first transmitter. He used this crude bit of apparatus in his first experiments in Italy in 1895.

When this is compared with the photograph taken in 1897 at Lavernock, South Wales, with a group of three Post Office officials, suitably moustachioed and bowler-hatted, proudly exhibiting Marconi's latest apparatus, the improvements he had made are obvious. The induction coil is a separate item on the right of the picture, and it is very much larger than the one from the black box. The four oscillator balls have also increased in size and are mounted in a row. The receiver has its coherer connected to the trusty Morse inker with its reel of paper tape for message-recording.

From 1898 until the successful achievement of the "Four Sevens Patent" in 1901, Marconi had been working hard on producing his next great improvement. He was acutely aware of the poor signalling efficiency of his apparatus, the menace of "double sending," and the hopelessness of any real take-over of cable business unless the public could be satisfied that wireless telegraphy was secret and could not be eavesdropped on by all and sundry. Critical, or selective tuning, once he had managed to perfect it, answered these three disadvantages in one bold stroke. By ensuring that the maximum power was transferred from the transmitter to the aerial, and from the receiving aerial to the set, it ensured that the signals sent out really were as powerful as the transmitter behind them. As before, this advance did not consist of a completely new discovery of an unknown scientific principle, but in the way it was applied for practical purposes. He achieved selective tuning at both ends of his system by controlling the frequency of the oscillating spark at the transmitter, and "tuning" the receiver so that it would respond to that wavelength and frequency, and no other. Tuning is now such an elementary part of all radio reception that it is difficult to imagine that before this time transmissions were made in a completely haphazard manner. Of course, in time tuning did not ensure secrecy of messages, since anyone with suitable apparatus can pick up the same signals; so codes, and later, "scrambling" devices were used to counter this. The millions upon millions who nowadays "tune in" to their favourite radio or TV programme are unconsciously paying tribute to Marconi's "Four Sevens" idea. As early as 1900 he had demonstrated what he called "multiplex" wireless by connecting two different receivers to one aerial antenna, and when they were tuned to different wave-lengths, they both worked. In 1901 he showed multiplex transmission across 156 miles between the Isle of Wight and the Lizard, sending two messages simultaneously from two transmitters, and allowing them to be picked up by two independent receivers standing one on top of the other. As one message was in English and the other in French, there could be no doubt of the success of selective tuning when the two tapes rolled out with their different messages, word perfect. As Fleming commented at the time: "So perfect is the independence that nothing done on one circuit now affects the other, unless desired." Marconi's early insistence on, and mastery of selective tuning paved the way for all real radio progress. Without such tuning, today's myriad messages would end in hopeless confusion.

Marconi's next quest was for increased range of transmission, culminating in the transatlantic feat. He believed basically that the key to this lay in the power used at the transmitter—and rightly so. But he also felt that if he could use taller and taller aerials with more elaborate and longer antennae, this would also help. He found a natural support for his increasingly higher "vertical wires" on the masts of large ships, and was quick to use such sites to the full. He early noticed, as at the Spezia trials, that natural electrical charges in the atmosphere—the "atmospherics" that have always been the bane of radio operators since those very earliest days—could and did interfere with reception whenever they were present. But, as in 1898 with his tests on the steam tug off Poole, he also noticed that strong winds and general bad weather had little marked effect on wireless on their own. Indeed, quite good results were obtained in fiercely driving rain and a howling gale. He knew already that tall buildings, especially if they had metal girders or supports in their construction, offered far more of a hindrance to radio waves than did ordinary rough weather, or indeed hillsides and cliffs, although he still wanted confirmation about the latter, and returned to the problem (first studied at Cowes) more than once until he was satisfied.

In the main, however, Marconi had the biggest field for experiment in these early years with his aerials, or antennae. He made serious attempts on Salisbury Plain in 1897 to use balloons to support his long aerial wire, but with continuing and unseasonable bad weather that autumn, had to abandon the attempt and try kites instead. He was not to abandon completely either of these ridiculously capricious devices as aerial supports for some years yet, and of course the first transatlantic signals were picked up by a kite-suspended aerial at St. John's. But as syntonic tuning became more general, and bad weather rarely seemed to get better, fixed aerial masts seemed to be the only answer, as indeed they were to be for decades and, to some extent, still are. With the fluctuating height and constantly changing angle of an aerial line held aloft by a wind-supported kite, selective tuning was impossible.

So began Marconi's aerial-building saga. At the Needles station he began with a really stout mast tall enough to carry a 120 ft. aerial wire free of all obstructions. This worked well, and when the permanent Poole station was built, a similar mast was erected there. This was described later by H. M. Dowsett, an engineer who joined the team there as an assistant, as "the Marconi three-mast set, 110 feet high, on the sandy foreshore, with some of its stay anchors likely to be under water at spring tide." (Incidentally, Dowsett has left a good picture of the casual remoteness of that first really important Marconi station that was to serve as the inventor's field headquarters for so many years. Arriving at the Haven Hotel to report for duty on his first day, he found that the so-called laboratory was in fact a square room on the ground floor of the establishment, much favoured by tourists and yachtsmen. The room had little furniture, only some benches, a small table and a few chairs. The all-pervading smell came from the paraffin-wax melting-pot used for providing the necessary insulating material on the circuit wires. He noticed two mechanics were busy making the intricate coherers, while a third was winding coils. Marconi was also busily occupied at some task on a bench, and merely looked up and "smiled amiably" when the new man introduced himself. After some time, during which Dowsett felt most awkward, Marconi handed him "a piece of metal no larger than a shilling and the oldest and smoothest of files, telling him to make some metal filings for a coherer." Dowsett went to work on his piece of nickel, filing away for half an hour to produce only a tiny heap of fine metallic dust, completely convinced that this was some kind of ritual joke reserved for "new boys." In the end, much to his surprise, Marconi told him he had produced enough filings to fill a coherer, explaining that as very fine dust was required, only the oldest, most clogged-up file was any good for the job!)

By now, Marconi was concentrating on aerial height, with bigger and better masts. He had more or less abandoned earlier attempts to increase aerial effectiveness by trying metal cylinder aerials, like the one used early in 1897 for the Lavernock-Brean Down link-up. This was suspended from a 30-ft pole on a cliff-top, and consisted of a cylindrical zinc cup, some 6 feet by 3 feet. For a time this was also used at the Needles station later in the same year. His great aim was now to thrust his antennae ever higher into the heavens, and he rarely built one below 100 ft. in height. The mast erected at Ladywood Cottage, Osborne House, Isle of Wight, was this height.

His *pièce de résistance* was the aerial installation designed for Poldhu. Here he wanted not only a really lofty antennae set-up, but a reliable and permanent one that would withstand the gales that blew in from the Atlantic he was soon hoping to span. Poldhu had been chosen originally for its remote situation facing the ocean with no physical or geographical obstruction in the line of the wireless waves it was hoped to send on their long journey more than 2,000 miles across the sea. The remoteness from the rest of England was also considered important at the time: the Marconi Company were at that time becoming well and very favourably established with the less ambitious applications of their system, and they felt it necessary to achieve all the privacy from the public eye that could be managed in case a possible failure of the "big thing" discredited them in the eyes, not only of Britain, but of the world. This lonely fastness on the West Cornish coast, far from any big centres of population, offered just what was wanted.

Building work began in October 1900 and was completed by January 1901. At once Marconi and Franklin carried out some preliminary tests to gauge the likely effectiveness of their plant. Using a purely temporary aerial system, they transmitted signals to Crookhaven, 225 miles away on the West Coast of Ireland, where reception was so strong and clear that Marconi felt quite confident of eventual success across the Atlantic. By August Marconi's most fantastic and certainly his largest brain-child stood in ethereal silhouette against the Cornish sky, a gigantic, twentieth-century electronic Stonehenge. It consisted of a vast ring of twenty vertical wooden masts, 200 feet in diameter, each mast being 200 feet high. Each mast was rigged to its fellow by a ring of wire at the top and at intervals down to the ground; there were innumerable stays and guy-ropes to hold the whole thing erect, and the uppermost ring served as a support for some 400 vertical hanging aerial wires. The whole edifice looked rather like the skeleton of a gasometer. The stone transmitter buildings stood inside the circle of masts, and other buildings were built near by.

From any point of view it was an imposing piece of work, but on September 17th, 1901 came the ferocious gale (some said it was a cyclone) that swept right along that craggy coast and demolished the Marconi aerial of aerials, splintering the masts as if they had been matches. The engineers said it would take at least three months to clear all the wreckage and build afresh. But time was vital and Marconi decided that perhaps after all a simpler aerial system might work just as well. So just two masts were erected, each 150 ft. high, with a triangular stay held taut between them. From this were suspended fifty-five separate copper wire aerials, about a yard apart at the top and tapering to ground level in the shape of a gigantic fan. This took only two months to build, and it was the one used in the historic transmissions to Newfoundland. In the months that followed this historic event, the Poldhu aerials were elevated to 210 ft. and suspended from an even bigger fan-shape, or rather an inverted pyramid, held taut by steel towers set in a square. An aerial system of almost identical design was also constructed across the Atlantic at Glace Bay, but this had more spacious buildings than Poldhu.

From these beginnings it was a natural step to enlarge and develop the basic aerial set-up devised at Poldhu after December, 1901, so that it grew into the bigger but similar installations that came to be built at Cape Cod, Clifden, Caernarvon, Chelmsford and elsewhere, leading to the extensive ten-aerial Marconi radio beam station built at Bridgwater in 1926, and on into the major broadcasting stations that then sprang up all over the world. Even today, for many purposes, major radio installations use steel pylon set-ups not unlike that first seen at Poldhu. Of course, as with all radio progress, the aerial saga was not one of unrelieved success and progress. There were many changes made in the design of the aerials themselves, and many puzzling disappointments were endured by Marconi and his team. With today's after-knowledge it is easy to see what the mistakes were, but at the time, these pioneers were exploring virgin country. As Marconi historian G. G. Hopkins says: "These trials and failures were the bitter roots from which that knowledge grew." In the early days at Poldhu they knew nothing at all of the effects of wave-length upon signalling range. They could only measure wave-lengths at all very inaccurately, and they had no means of measuring frequencies. The effect of daylight and darkness on radio transmission was known and studied, but it was still a baffling puzzle for which no satisfactory explanation had yet been found. To cap everything, all equipment was far from 100 per cent. reliable, and it was common practice to repeat messages over and over again to make sure they were picked up at all, while atmospherics frequently rendered all transmission and reception impossible.

In the early years of this century Marconi's path lay towards bigger aerials and longer and longer wave-lengths, coupled with yet more power at the sending station. So far no attempt had been made at all to do what now seems so childishly obvious that it is hard to believe it can ever have been overlooked: to amplify incoming signals at the receiver. However weak these were, they were all the pioneers had to rely on, and consequently the transmitting power was constantly increased in an effort to make reception louder and stronger. Today's incoming signals on any radio set are still far from over-powering, but when they are electrically amplified they become audible and as loud and strong as we require.

When Poldhu was built, Marconi realised that to span the Atlantic he would require a power plant bigger than anything ever even envisaged before, and he was fortunate at the time in being able to draw on the skill and knowledge of high-tension currents on a large scale of J. A. Fleming. Even so, the twenty-five kilowatt wireless power station they designed and built, the first of its kind ever seen, necessitated the difficult step of transforming the old Leyden jar type condenser battery and induction coil set-up into a real electrical engineering plant with alternating generators. A surviving photograph of part of the power-house shows the complicated but still crude-looking equipment that resulted, with its warning notices, CAUTION: VERY DANGEROUS. STAND CLEAR that must have seemed fantastic at the time, but which were correct enough in the context of the high-tension voltage being used. Actually it was Fleming who solved the problem of generating enough current to leap across the two-inch spark gap with the single action of a transformer on a condenser, as had always been used before, but without raising the transformer voltage so high as to be impossible to handle. He did this by devising a special method in which low-voltage current was raised to 20,000 volts by transformers and used to charge condensers, which discharged their current through oscillation transformers across the spark gap. This enabled the spark-producing current to be "doubled up on itself" without involving unmanageable voltages.

Although this ingenious power plant was strong enough to send signals over 2,000 miles, it can be realised now that much of the considerable power used was in fact wasted, diffusing itself in all directions instead of being directed towards the receiving apparatus. Until a really worthwhile concentration of transmitting power could be achieved, it seemed that the range achieved for this reason would always be small in proportion to the power output employed. Marconi was very conscious of this impelling problem, and his first major step was his patenting, in 1905, of his original horizontal directional aerial. With this, the outgoing waves could be sent out only in the direction required, without wastage of transmitting power. Looking back on this step, Marconi said: "In 1905 my experience led me to patent and introduce the horizontal directional aerial, which at once brought about the most marked improvement in the strength of signals. It is from this point and by this new discovery that real progress in long-distance work is dated." Although this aerial proved of great service to existing long-wave systems at the time, it was later to be spectacularly superseded by the Marconi-Franklin short wave beam system in the early 1920s, which completely revolutionised the whole technical field of wireless communication and paved the way for today's instant short-wave radio network across the globe, and beyond it into space.

Franklin and Marconi started working on this in 1916 in Italy, hoping to make possible a limited short-wave beam system for the Italian Navy in wartime that would give the least chance of interception by the enemy. The major experiments were carried out in later years at Poldhu, with Franklin at the English end of the fantastically successful link-ups and Marconi cruising many hundreds of miles away in *Elettra*. This was to be the last important work done at the Poldhu station, which ever since the construction of the bigger station at Clifden in 1906 had ceased to be of major commercial importance. It did however continue to serve as a transmitting centre for news, navigational information and private traffic for the various shipping lines, and up until 1922 the name Poldhu was a friendly and trusted link for countless mariners. By the 1930s, the need was for numerous short wave beam stations all over the world, and a remote, pioneering type of station such as Poldhu had no further usefulness, and it was finally dismantled in 1933.

Marconi himself probably spent fractionally more time at his Poole station than at Poldhu, but the latter, with its long and chequered history, symbolises his work more than any other place. To quote G. G. Hopkins again: "The name of Poldhu Station, the scene of so much intensive effort, so many heartbreaking setbacks and brilliant successes, so many long night-watches on those lonely cliffs, is linked for ever with the fascinating story of the growth of the wireless industry." After Poldhu's little stone buildings were demolished, the site was cleared and the Marconi Company erected a handsome granite obelisk, to commemorate for all time the feats that Marconi performed there. Beneath the column of local stone that tapers challengingly to the sky are inset on each side four bronze plaques bearing these words:

> One hundred yards North East of this column stood from 1900 to 1933 the famous Poldhu wireless station, designed by John Ambrose Fleming and erected by the Marconi Company of London, from which were transmitted the first signals ever conveyed across the Atlantic by wireless telegraphy. The signals consisted of a repetition of the Morse letter "S" and were received at St. John's, Newfoundland, by Guglielmo Mar-

coni and his British associates on December 12th, 1901.

The Poldhu wireless station was used by the Marconi Company for the first trans-oceanic service of wireless telegraphy which was opened with a second Marconi station at Glace Bay in Canada in 1902. When the Poldhu station was erected in 1900, wireless was in its infancy; when it was demolished in 1933, wireless was established for communication on land, at sea, and in the air; for direction finding, broadcasting and television.

From the Marconi Company's Poldhu Station in 1923 and 1924 Charles Samuel Franklin, inventor of the Franklin Beam Aerial, directed his short-wave wireless beam transmission to Guglielmo Marconi on his yacht *Elettra* cruising in the South Atlantic. The epoch-making results of these experiments laid the foundation of modern high-speed radio-telegraphic communication to and from all quarters of the globe.

The site of this column and some six acres of land on the edge of these cliffs together with the cliffs and the foreshore beneath them were given to the National Trust in 1937 by the Marconi Company to commemorate the pioneer work done at the Poldhu wireless station between 1900 and 1933 by its research experts and radio engineers.

## Chapter 8

# THE AGE OF DARKNESS

In Marconi's own account of the first transatlantic broadcast, already quoted, he gave some idea of the crude simplicity of his receiving apparatus at St. John's. He did not however explain that his coherer was of the latest type he had designed, being filled with mercury instead of filings and which worked on a self-restoring basis. It therefore required no operator to tap it to loosen or separate the minute particles of metal. Nor did he explain that this time he had fitted up an ordinary telephone earpiece into his aerial-to-earth circuit. This was done to make quite sure the real "S" signals were coming through, instead of relying on the Morse inker, at this stage rather too impersonal. Thus it was made possible for the beginning and the end of each train of radio waves from Poldhu to be heard as distinct clicks in the earpiece, taking advantage of the ability of the human ear to distinguish between the actual signal clicks and the inevitable crackle of atmospherics, which the Morse recorder simply could not be relied upon to do.

But Marconi's main ally in his 1901 feat was invisible and only recognised as helping him years later. With the main exception of the inventor himself, almost everybody else had maintained all along that the curvature of the earth would prevent long-range transmission of wireless waves, which then were believed to travel in straight lines. The simplest comparison given was the impossibility of seeing a ship over the horizon. Even the considerable oversea distances already achieved in the earlier tests had not convinced the doubters—and they were in the majority. In the light of what we know now it seems unlikely that Marconi himself knew exactly why his waves would reach North America: he merely felt instinctively that they would. At any rate, and not for the first or the last time, his "trial-and-error" pioneer work had thrust far ahead of contemporary thought.

The orthodox scientists had no great liking for the way this untrained, upstart amateur was proving to be possible what they considered impossible. So a number of physicists and mathematicians set to work to explain the phenomenon that Marconi had so confidently uncovered. In 1902, a British scientist, Oliver Heaviside, and an American, Dr. A. E. Kennelly, working independently, came up with the answer. They showed that above the earth lay a layer of ionised particles (originally called the "Heaviside Layer"), which somehow or other reflected back to earth radio waves that reached it. Later, in 1925, the British scientist Sir Edward Appleton showed that there were in fact several layers at varying heights. Each layer has this property of reflecting back radio waves to earth, as we now know. The waves fall diagonally back to earth, whence they bounce upwards again to the ionosphere, covering the earth in a series of gigantic diagonal hops until they lose all their power.

The effect of the ionosphere layers now has a far greater importance for radio communications than can ever have been imagined in 1902. Intense radiation from the sun acts on atmospheric gases of varying density, and affected by the earth's magnetic field, produces layers of ionised or electrically charged particles at heights between about fifty to 500 kilometres above the earth. These layers are not very well defined, and their characteristics change throughout the day, some of them becoming de-ionised, or discharged, after terrestial sunset, and all of them becoming greatly affected during periods of sunspot activity. This whole general region is termed the ionosphere, and its many mysteries are still far from all being solved even today, although current research into them is being greatly helped by the various scientific satellites now orbiting the globe. Radio signal waves are reflected in different ways by the different layers, but those striking any layer obliquely have the best chance of being effectively reflected downwards again. Those that strike a layer more or less vertically are less readily reflected, and above certain frequencies waves actually pass right through the layers and are lost. Four layers are now generally recognised: the D layer, which is the nearest to the earth, about seventy-five to ninety-five kilometres up, and which is very dense, tending to absorb rather than reflect medium-wave signals in daylight; the E layer, the original Heaviside, or Kennelly-Heaviside layer, at about 110 kilometres height, and the F 1 and F 2 layers, extending between 200 and 400 kilometres, and known collectively as the Appleton layer, which make possible today's long-range, short wave radio communication.

Of course, some waves emitted from a transmitting aerial do just move outwards horizontally. They are known as ground waves, and they serve only a limited area before fading badly due to absorption by the earth. Nowadays, ground waves are used by local medium-wave broadcasting stations and all V.H.F. (very high frequency) stations. These stations have aerials specially designed to put as much of their energy into the ground wave as possible. With normal aerials, however, a good deal of the radiated energy will escape upwards away from the earth, forming what is known as the sky wave, and it is, largely speaking, the sky waves which are the ones regularly if somewhat imperfectly reflected back by the ionosphere.

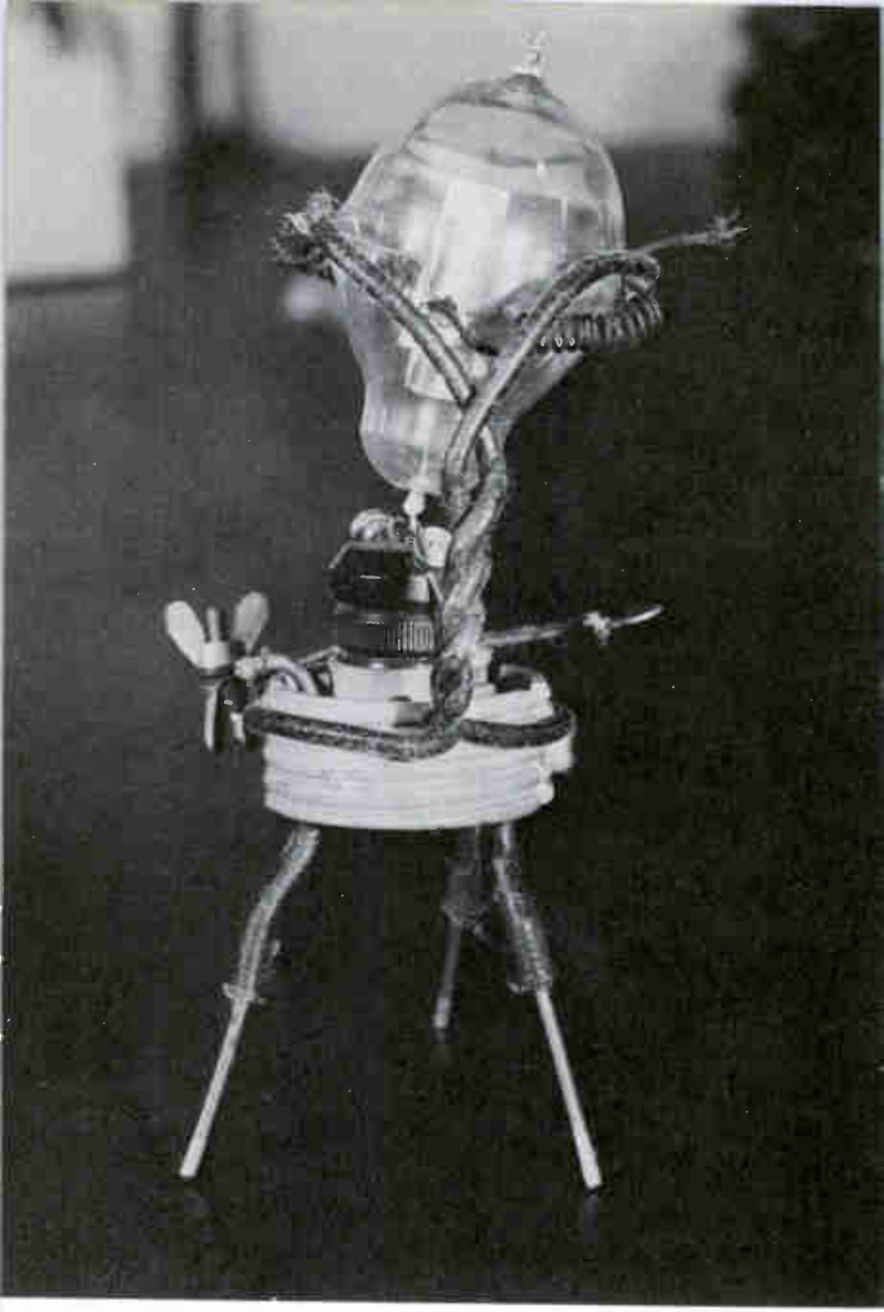
If we had to rely entirely on ground waves today, transmission range would be generally restricted to a few hundred miles, unless enormously long waves, miles in length, and very low frequencies, coupled with very high transmitting power and huge aerial systems were used, of the same type that limited Marconi's early work. In 1901 the ground waves sent out with the limited power of Poldhu would never have crossed the Atlantic, so it is plain to us today that the transatlantic success was achieved only by reflected sky waves, although none of this was understood at the time. What Marconi was eventually to discover, after years of experiment, was that the comparatively low-powered, ultrashort waves of very high frequency were the ones that make world-wide communication really possible, thanks to their return from the ionosphere layers. Yet even today, of course, such communication can vary from day to day and be adversely affected by sunspot conditions. The only real answer to these drawbacks is the now universal use of very high powered signals narrowly directed, or beamed, on carefully chosen frequencies, and picked up at the receiving end by good, efficient aerials.

In 1902, on the historic experimental trip on board the liner *Philadelphia*, Marconi and Franklin (who was acting as the telegraphist) encountered the puzzling "daylight effect," whereby range was better and signals stronger by night than during the hours of daylight. This is now explained quite simply by the sun's radiation affecting the density and the electrical content of the gaseous ionosphere layers. After dark, some of these become less dense and so absorb radio waves less, and reflect them more. All the layers are altered by the daily changes between sunlight and darkness, with the broad general result that radio reception tends to be better after dark, although there are also other minor differences. None of this was understood by Marconi at the time; it was only with the recognition of the real value of very short waves, bounced back and forth between the Appleton layers and the earth, that the disadvantages of the "daylight effect" were finally overcome.

The trouble at the time lay in two directions. First, was the inevitably incomplete knowledge of radio waves, their properties and the conditions in which they operated. Second was the continued use of inadequate apparatus. Marconi's lay-out of equipment in the *Philadelphia's* wireless room on that important voyage was far from impressive; in fact it was quaintly crude and inefficiently primitive. After all, this was still "the age of darkness," as the great American pioneer E. H. Armstrong termed radio's earliest "hit or miss" years. The power came from six quite small Leyden jar (condenser) cells linked in series in a wooden box; the induction coil, although modest in size, was the largest item, although its spark gap and electrode knobs were very small; a tuned receiver was used, however, and the Morse tapper and Morse inker, with its spool of paper tape, completed the gear on the radio bench. All connecting wires, including the vital one out of the cabin up to the top of the 160 ft. aerial fastened to the liner's mast, were loosely draped or hung in seemingly haphazard array from one piece of apparatus to the next. The wonder is that such an obviously amateur "station" functioned at all.

However, Marconi was acutely aware of this second drawback to the continued progress of his work, and he laboured tirelessly to improve matters. His next success lay with the magnetic detector, designed to replace the already outdated coherer. Whatever form the latter device took, it was especially vulnerable to outside influences on board ship, where the throb of giant engines, and the rolling and pitching on the ocean as well as electrical impulses affected it. The magnetic detector

23 Sir John Ambrose Fleming, who worked closely with Marconi, was the inventor of the thermionic diode valve, or the earliest version of the radio "tube." Earlier he had helped to set up Marconi's wireless station at Poldhu with special attention to the creation of high tension currents for broadcasting.



24 Fleming's experimental model of the first diode, or radio tube, which he developed in 1904. Eventually this was to revolutionize the broadcasting of wireless signals.

was his answer: an instrument based on a scientific fact first demonstrated by Sir Ernest Rutherford in 1895. Marconi used an endless band of soft iron wire on two wooden pulleys, rotated by clockwork and passed close to the poles of two horseshoe magnets; as the band passed from the influence of one magnet to another the magnetism was reversed. The wire band then passed through two coils of insulated wire, one of them connected to the aerial and the other to a telephone earpiece. From Faraday's work he knew that if a magnet is moved near a coil electric current is induced; the same thing applies if the magnet is stationary and the coil moving. While the state of the aerial coil remained the same the magnetic condition of the wire band did not change. But when electrical impulses came through it and changed the magnetic condition of the wire a current was induced in the earpiece coil and the fact was recorded by a click in the earpiece.

He made the prototype very quickly one day at Poole in 1902, after cycling into nearby Bournemouth to buy a quantity of very fine wire at a florist's where he had often seen a girl assistant using it to tie up flowers for corsages and button-holes. Again it was a basically simple device, robustly made in rectangular box-shape, with a moving wire belt moving from one spool to another rather like on a modern tape-recorder. This belt passed beneath a tiny, finely-wound coil magnetised by two simple horseshoe magnets mounted together flat on their sides close to it. Later described as a "jewel of workmanship," this detector worked so well that it could detect the minutest fluctuations in the current caused by the incoming signals and fed from the aerial to the belt. Equally important was the fact that the output from the detector was connected to a pair of headphones, which from then on became standard radio equipment, as of course they still are.

Yet another worry caused by the inefficient coherer was that gadget's inability to tell the difference between the wanted incoming signal and the unwanted (and often more plentiful) current fluctations caused by atmospherics. The faithful old Morse inker was prone to produce a confused signal record for this very reason, whereas the keenly attuned human ear could nearly always distinguish between the two types of sound. On account of its beautiful simplicity combined with robustness, the magnetic detector, swiftly patented, was particularly well suited for use on ships, where it remained in standard use for some years. It is noteworthy that many years later, during the darkest days of World War II, this same electrical principle was destined to come to the aid of Allied shipping in the form of the highly successful "de-gaussing device," whereby a wire belt or girdle round the outer hull of metal vessels, energised by an electric current, neutralised their normal magnetism and so made them immune to German magnetic mines. Until Marconi took up the principle for his own purposes, however, it was considered to be of merely academic scientific interest.

By now other workers were being inspired by Marconi's bold and resourceful example. Rather more sensitive than his magnetic detector, was the invention of two Americans, H.H.C. Dunwoody and G.W. Pickard. This was the famous crystal detector, simplest of them all, and destined to be a popular piece of amateur and domestic radio equipment in the earliest days of broadcasting. This was just a small fragment of galena, natural lead sulphide, or common lead ore, held tightly in a metal cup or clip, with a piece of thin wire (the "cat's whisker") that tickled the surface of the mineral, some spots on which worked better than others. The incoming wireless signals, picked up on the outside aerial, were fed to a simple tuner to select the required station, then on to this crystal detector which provided sufficient audible frequency power to work a pair of headphones. (In later years, some crystal receivers picked up local transmissions strongly enough to operate a horn loudspeaker.) The crystal detector relied entirely, as did its predecessors, on the electrical energy picked up by the aerial, but it was even less liable to undesirable disturbance by outside electrical discharges, including the hated atmospherics. Its disadvantages were that the "cats whisker" wire was easily jarred off the selected sensitive point, even in the middle of a message, which made it useless at sea. In due course it was found that a piece of carborundum held tightly in a metal cup with a carbon electrode pressed firmly against its surface would work just as well, and once adjusted did not slip off so readily. For a time this adapted crystal detector was used on board ships fitted with wireless as a supplement to the standard magnetic detector. Other mineral substances that could be made to work almost as well included iron pyrites and even coal. Crystal detectors were very cheaply made and were simple enough for any amateur to construct readily. What was not always realised was that with them, everything depended on the aerial, and to work well they needed a highly efficient aerial system.

More directly concerned with Marconi again was the far greater and much more important discovery next on the way. This was the efficient radio valve, the device that was to swing wireless into worldwide reality. As early as 1883 Thomas A. Edison had noticed that when certain substances are heated in a vacuum they emit particles (later discovered to be electrons). These negative charges of electricity can be attracted across the vacuum to a conductive metal plate, or electrode, which collects them. By 1904, J. A. Fleming, after his Poldhu triumphs, had noticed a similar effect from the white-hot tungsten filament of an ordinary electric lamp, and he decided to adapt this principle for an improved type of detector. In that year he introduced his so-called thermionic diode detector, later to become known as a valve (or in some countries, a tube). This carried forward the principle Edison discovered into the realms of wireless reception. It was called "thermionic" because it involved applying heat to one electrode to produce the flow of electrons. Although pure metal like tungsten can be made to emit a steady flow of electrons it first has to be heated to almost white heat, and in due course it was found that by coating a metal electrode with various metal oxides (barium, calcium, strontium are the ones most used), a copious electron flow can be achieved at considerably lower temperatures, generally around 800° c.

"Diode" is the name given to a two-electrode device, and the term "valve" was chosen because these vital pieces of equipment are one-way regulators analogous to the mechanical valve, as in a pipe, in that they permit the flow of electricity in one direction only. A simple diode valve consists of a glass bulb encasing a near-vacuum, with the two electrodes mounted vertically side by side inside. The emitting electrode, always called the cathode, is in the form of a fine-gauge tube coated with the oxide and encasing the filament which acts as the heating element. Once the valve has "warmed up" or allowed its cathode to reach maximum working temperature by means of the current flow passing through it like a lamp filament, its electron flow starts. The electrons move invariably towards the other electrode, or anode, usually a thin metal plate of nickel, nickel-chrome and copper, never in the opposite direction. As long as the current flows into the heating element of the valve, the heat generated raises the energy of the electrons in the cathode coating and they readily—and steadily—escape across the vacuum to the anode.

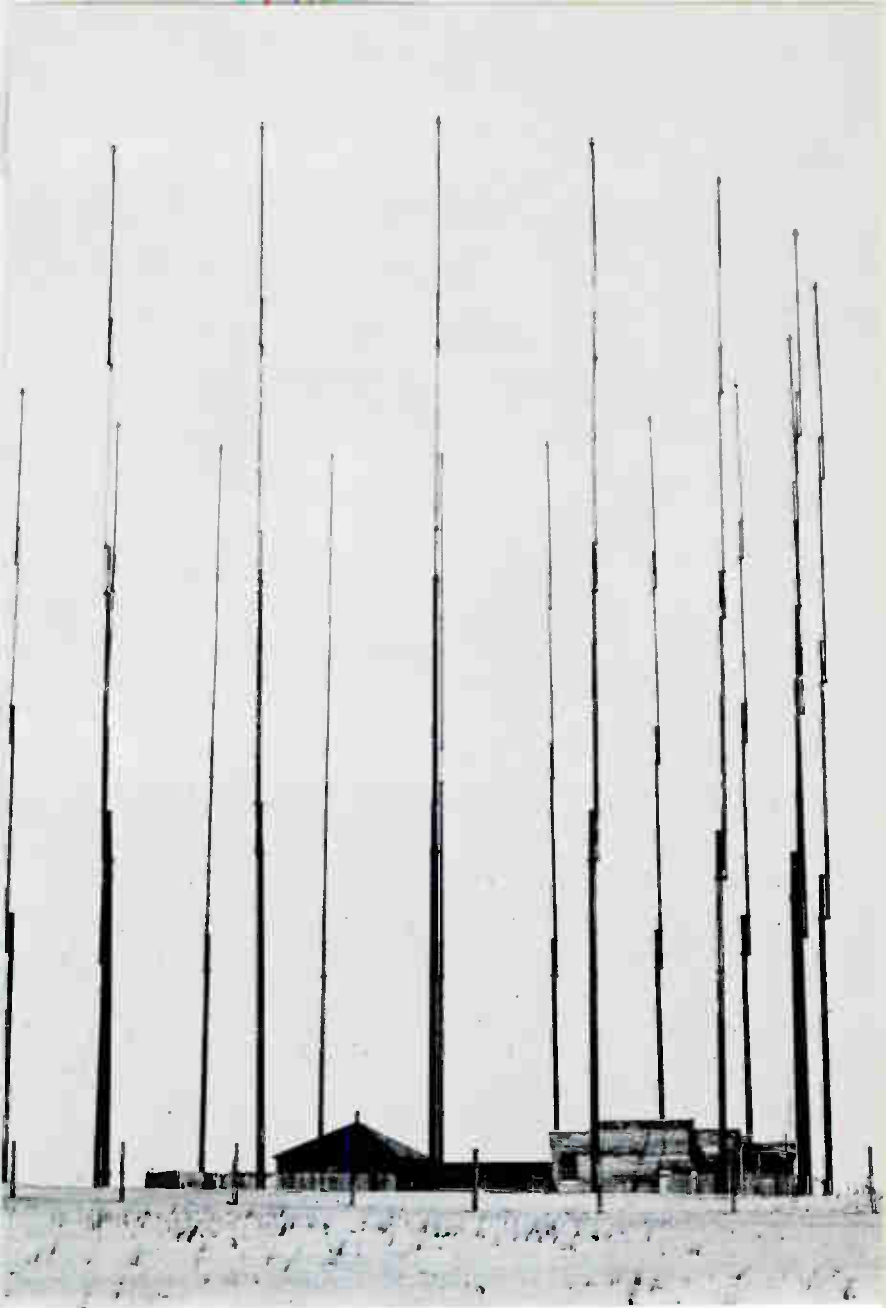
The advantages of this device in wireless receivers was immediately obvious. The old coherer, the magnetic detector and the crystal all in themselves acted as crude valves in that they allowed the intermitting or alternating flow of electrical energy to move one way only, and so allowed it to be intercepted as a recognisable signal. Fleming's valve brought the whole process under finer control, since the current flow can be controlled by the positive voltage charge applied to the anode, whilst the signal energy passed through the valve from terminals, or pins in the base, independent of the heating element. A few years later, in

1906, the American inventor Dr. Lee de Forest showed that a wireless valve could be made much more useful if a third electrode, which he called the "grid," is inserted inside the vacuum between the cathode and the anode. Then, if a change of voltage supplied to the grid is made, a corresponding but much larger change of voltage can be produced at the anode, or exiting electrode. This meant that for the first time a valve could be used as a simple amplifier, "blowing up" the signals received from the aerial. This three-electrode valve came to be known as a "triode," which is the basic form radio valves took in the years that followed.

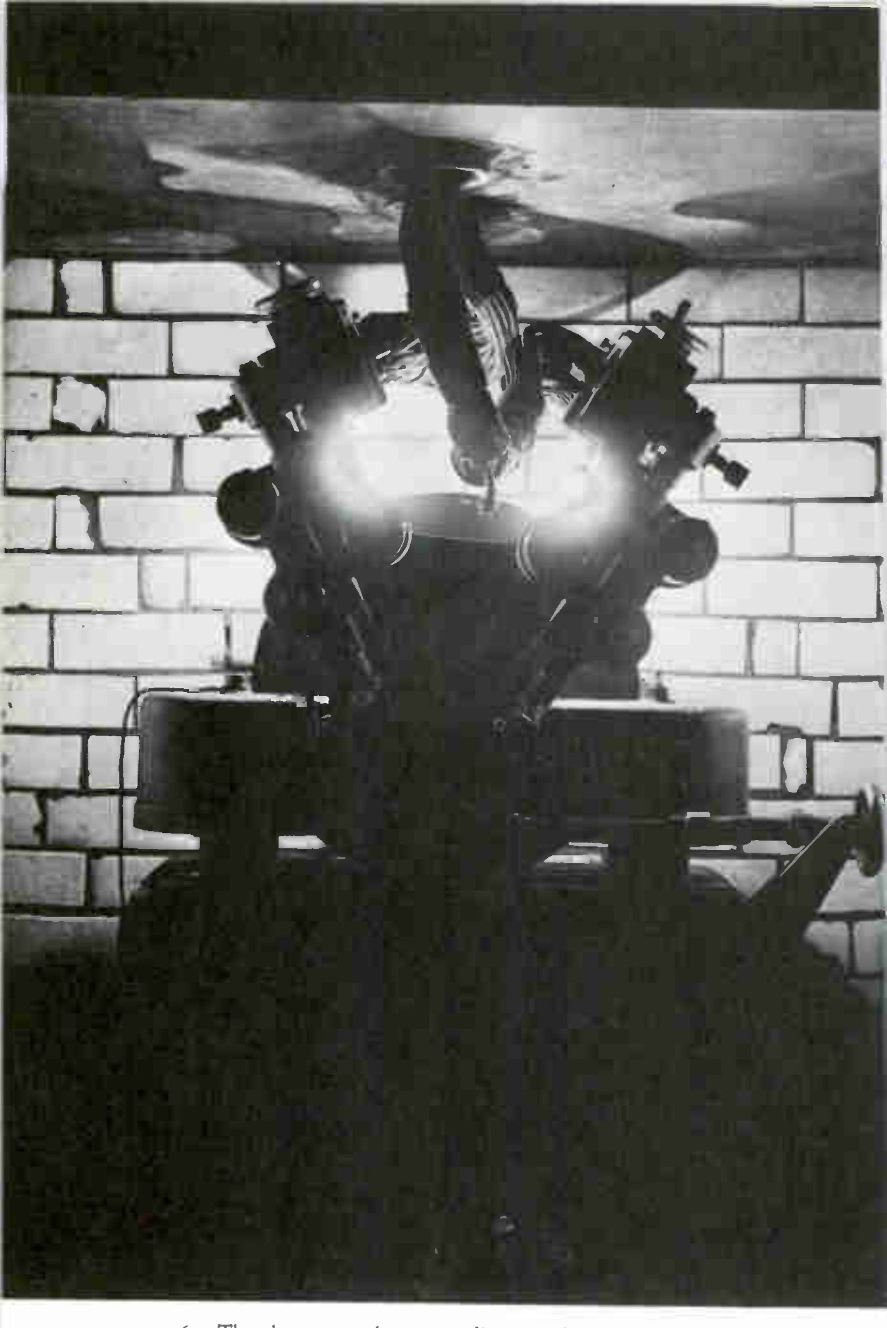
For more than forty years, until the discovery of the transistor in 1948, radio equipment everywhere that included amplification used one or more thermionic valves, and even with the transistor, much practical radio television and radar, on both the receiving and the transmitting sides, involves the use of valve equipment stemming from Fleming's 1904 innovation. (In passing, it is worth mentioning that the more recent reversion to mineral semiconductor material in place of the thermionic valve, with its widespread adaptation of tiny portions of pure germanium or silicon transistors, which perform the same task without the need for high working voltages to supply heat, and which last so very much longer than a fragile, expendable valve, is but a throwback to the original crystal detectors of the early 1900s, though of course much more efficient).

It would be pleasant to record that the thermionic valve, diode or triode, revolutionised radio overnight, but this did not happen. Marconi was pleased with Fleming's initial advance, though like everybody else he regarded it merely as an alternative to his own magnetic detector. De Forest's great improvement (called for a time the "audion"), remained for some years a mild curiosity from across the Atlantic. It was regarded as rather more sensitive than the Fleming valve, but not so reliable, and for a time very few were made or used. Gradually, however, the merits of the three-electrode came to be widely recognised.

It seems incredible now that progress was so slow, yet it must be recorded that Marconi himself did not at first appreciate just how the valve would completely revolutionise his work and its eventual development. Not least was his blindness to the need for a definite manufacturing plan for supplies of valves. Looking back on the occasion of the fiftieth anniversary of the Poldhu-Newfoundland transmission, C. S. Franklin declared: "It has seemed to many people that the development of the three-electrode valve has been slow, but I suggest that the truth is that full appreciation and utilisation of its possibilities has had to wait on



25 Wooden aerial masts at Marconi's station on Cape Cod, Massachusetts in 1901. These, and the similar masts at Poldhu across the Atlantic, were destroyed in fierce storms within weeks of each other. Marconi then moved to Newfoundland where he eventually received the signals sent out across the Atlantic from Poldhu.



26 The huge synchronous disc spark transmitter set up at Poldhu in 1914. It is shown on the night of August 4th when it was transmitting the news of Britain's declaration of war on Germany to shipping. Soon after this these powerful spark transmitters were superseded by the far more effective diode, or radio tube.

the discovery of the necessary manufacturing and vacuum techniques. A very similar delay has occurred in the case of cathode ray tubes. Looking back it has always seemed a pity that the Marconi organisation did not establish its own valve factory earlier. Time and time again development was held up by the difficulty of getting special valves made."

The invaluable work of Fleming and De Forest was eventually carried further by Captain H. J. Round of the Marconi Company, who gave it fresh impetus. He devised the first very small valve for amplification during World War I and in 1921 persuaded his now converted Chief to sanction the construction of the fantastic first high power valve transmitter at the Caernarvon Transatlantic Station, which operated on forty-eight giant-size valves, banked vertically.

Franklin certainly also deserves some credit since he inaugurated many patents himself for improving the thermionic valve. But his name earned a sure place in the annals of radio progress much earlier when he designed and made the first multiple tuner in 1907. This clever device was always used thereafter with the magnetic detector, making tuning in to required wave-lengths simpler and much more selective. It worked by tuning the aerial and the detector circuits simultaneously. It proved to be another sure step in the right direction, but as so often happened in the saga of world radio, progress was slow, dribbling along in little fits and starts.

In the first decade or so of the twentieth century Marconi, still puzzled by the vagaries of daylight and night reception, met the problem as he saw it in characteristic fashion. He experimented a great deal to extend the range of his transmitters during the daytime. After much trial and error he satisfied himself that very long wave-lengths gave him an improvement in daylight reception. He also found it easier to generate higher power when using them. There was little more conscious thought about the matter, and transoceanic wireless communications went down the weary road of longer and still longer waves.

Once a considerable degree of enhanced safety had been given to world shipping, Marconi —and indeed other pioneers—concentrated most of their efforts in competing financially with the solidly entrenched submarine cable systems. Higher and higher power through longer and longer waves, aided by bigger and better aerials and more sensitive detectors was the cry. Some of the waves used at this time were over 10,000 metres in length, and to radiate them masts had been built 1,000 ft. tall. Soon after the original Poldhu feat the transmitting power was increased there and at Glace Bay to fifty kilowatts, and before

World War I the power at some stations was raised to the then phenomenal heights of 500 kilowatts—still without finally mastering the deadly jangle of "static" or atmospherics, liable to be encountered anywhere if electrical storms were brewing, and always especially bad in the tropics. Naturally, as higher power was used, so the static came in stronger, too. It was an infuriating situation. Brute force methods were obviously not going to counter the power of the natural elements: that could never be finally vanquished, but it needed rapier tactics, not steam-roller ones. All this was still to come.

For the present, Marconi's company, like the others that had grown up in its wake, concentrated on the same track, putting a lot of their resources into transmitting ever more powerful sparks. Although in fact any oscillating electrical circuit will emit radio waves in the way that a spark does so well, the radiation of the old spark transmitter was always very inefficient unless the dimensions of the aerial set-up carefully matched the length of the waves used. Few spark waves could be confined to definite, accurately-measured wave-lengths. After all, the biggest spark of all, lightning, emits waves on such a broad front that it causes a crash of interference on every radio receiver within range—no matter to what wave-length the set may be tuned for reception. As radio stations increased in number, the crude spark emission tended to overlap all too easily and cause inter-transmitter interference. Financially, too, it was a horrifying prospect, requiring ever larger amounts of capital investment for producing transmitting equipment to match, or better still, to master the next fellow's. Money poured not only into the old-time condenser gap spark, but into other types of spark emission—quenched spark, timed spark, Marconi's own rotary spark and the arc spark, as well as others. In time, high frequency alternating generators provided the colossal power, some of it being directed through long-wave vacuum-tube generators.

Franklin even tried—unsuccessfully—to design power generators having high-speed mercury vapour jets issuing from electrically-charged metal cylinders. By night, long-distance communication was often perfect, but with the coming of day, power waned and atmospherics could easily blot out the most powerful transmitter. Marconi made a final fling in this blind-alley direction with his huge synchronous disc spark transmitter set up at Caernarvon in 1914, with massive condenser coils over 6 ft. in diameter, and connecting cables as thick as young tree trunks! The wide bands of waves broadcast by even the best of the spark transmitters inevitably reduced the possibility of really careful tuning, a fact now so perfectly achieved that Marconi himself would marvel at it.

Two other points relating to the age of the spark are worth remembering. We find it hard today to understand the early pioneer's dedication to the spark transmitter, yet it was all they had to transmit by. And if we ever doubt the simple transmitting power of the spark, we do well to recall that nowadays sparks can play a part in radio and television, even if it is an unwanted one. What we call interference on a radio programme or TV screen is caused by often quite small, and in themselves totally innocent sparks, emitted as a byproduct of some other process (in the ignition system of a car going by on a nearby road, in the electric motor system of a neighbour's do-it-yourself power-drill or vacuum-cleaner or home movie projector), but still doing their radio-wave feat as of old. Nowadays we have to fit suppressors on such machinery to cut out this type of spark transmission. The second, happier remembrance of the spark is the way radio operators up and down the world, especially at sea, still answer to the name of "Sparks," affectionately given to their original predecessors who used just that. Many of the world's services and other organisations still use a graphic representation of a spark (often with emitted "lightning" zig-zags) to denote radio, radio work, or radio engineers on badges, crests and motifs.

By 1912-1913, Marconi and others had begun to see the clearer road ahead on which the thermionic triode would not only detect the incoming signals but also amplify them as required, which was eventually to do away with the need for vast power at the transmitting end. In addition, not long after the worldwide emergence of the triode valve, experimenters began to wonder what would happen if some at least of the output signal leaving the valve were passed for a second time through the valve. They found that this simple idea increased the amplification power of the valve enormously. Called "regeneration," this further step was to play a big part in the years that lay ahead, vastly increasing the sensitivity of radio receivers generally.

In the words of E. H. Armstrong: "While we damned nature for its perversity in creating the static, we were happy about our ingenious transmitting and receiving equipment, which worked so well in the absence of disturbances. The idea that there might be a way of working with the forces of nature, rather than against them, seems to have been beyond the imagination of those working in the art. Another basic discovery was required to get off the dead-end road. Marconi was destined to make that discovery . . ."

## Chapter 9

# THE SECOND GREAT DISCOVERY

A great deal of Marconi's time during the years between 1902 and 1914 naturally was taken up with planning and administering the rapidly expanding business of his companies and organising the opening of their various stations. In addition, addresses, lectures, publicity visits to America and lawsuits to defend his various patent rights inevitably ate into the time he could devote to research work.

Nevertheless, his fertile mind constantly sought to delve ever deeper into the practical ramifications of his invention and the progress it had to continue to make. The coming of World War I gave such thought and work added impetus, as wars always do to all scientific development. Once Italy entered the war in 1915 he had every incentive to come to grips with the problem of exclusive, short-range transmission, and with it, to master once and for all the magical short waves. World War I was not in fact the first conflict to see the use of wireless: in both the Boer War and the Russo-Japanese War of 1904-1905 some small use had been made of what were then still being called "Hertzian waves", but the 1914—1918 conflict was eventually to enlist radio's fullest possible aid on both sides. At the outset of hostilities, however, only the navies were in any way equipped to fight with wireless waves as well as guns. Aerial warfare was virtually untried, although aircraft-to-ground radio communication had been achieved as early as 1910. As for the armies, they regarded wireless telegraphy merely as "a possibly useful adjunct to visual and land signalling."

But once national survival was threatened, such scepticism was soon thrown overboard, and it is significant that although long waves were still of course widely used, the real progress and the real successes came with short waves. Experiments with them went ahead in more than one country. In Britain, as early as November 1914 H. J. Round, then a lieutenant, put to practical use in France the work he had been doing at home on wireless direction-finding. By using amplifying valves of his own design he achieved notable advances in sensitivity and general performance, and with the help of other young officers managed to set up special stations to intercept all messages transmitted by enemy stations on the ground or in the air. In particular, the Germans used small gun-spotting aircraft in their range-finding, their little "buzzer" sets operating on short waves of between sixty and 100 metres only.

From these craft logged messages warning of impending bombardments were often passed to specific target areas.

Round was soon recalled to England to perfect similar direction-finding installations for anti-U-boat work, but one of his assistants. Lt. F. Adcock, went very deeply into such short-wave work with the result that he was able to devise a special form of direction-finding aerial to avoid the after-dark unreliability of signals. After the war, at Marconi's insistence, the Adcock idea was further developed, culminating in the highly practical Marconi-Adcock Direction-Finding System of 1930, which was widely used in an adapted form for airport direction-finding in World War II and afterwards.

Marconi himself took Franklin to Italy to investigate the practicability of very short wave transmission, with a view to providing the Italian Navy with a transmitting wave which could not be detected by the enemy. This hush-hush work achieved some success, notably in the two to three-metre range, using a small, compressed air spark-transmitter that proved very reliable for such work. The two pioneers obtained good results with a few miles' range, finding joy in the need for only low power and small aerials, so easy to use with directional reflectors. Franklin also made the interesting discovery that if both transmitter and receiver were located high above the ground, a great increase in range could be obtained, a fact later to be of immense value in aircraft radio.

Once the war was over, Marconi's resumed interest in these short waves could not be quenched, and once he was owner of the *Elettra*, thoughts about them rarely left his mind. Short waves had a magic of their own—as they still have for many enthusiasts and listeners. Short wave directive beams, such as had been used in wartime Italy, seemed to hold the key to the future.

Franklin was already in the vanguard of short wave research when the inevitable question arose as to what practical use could be made of these short waves. It was suggested that a short wave link be established between London and Birmingham and that he be given the task of implementing it. He chose a wavelength of approximately fifteen metres, partly because that was about the shortest reliable wave obtainable with the valves then available, and partly because a directional reflector for that wave would be easily manageable. Marconi himself was not convinced that so short a wave would be the answer. In fact, he bet Franklin five pounds that nothing would come through. In the event the link-up was very successful, working well many hours a day, and Franklin duly collected his money! The actual transmission path of about 100 miles between the London end at Hendon, and Birmingham was sufficiently short for the loss of range—the old "daylight effect"—not to occur, and Franklin's telephone circuit, although not then a commercial proposition, did show the inherent potentialities in this new line of work. The transmitters at each end were of only about four kilowatts power, then extremely low for 1920. Round joined in with waves of about 100 metres, which effectively linked a station at Southwold, Suffolk, and the stage was set for trials over much greater distances to ascertain whether such short waves would carry that far.

Now for the first time we begin to hear about the growing numbers of radio amateurs in various countries who had been actively interested in radio since inexpensive crystal detectors became available. The valiant, warm-hearted army of radio "hams," perhaps 350,000 strong all over the world today, were but a small, ill-equipped force in those days, but their keenness then, as now, knew no bounds. Ever since the days of the first big shipping disasters involving wireless, the amateurs had been allowed, by general international agreement, to use, or as they call it, "work," only the so-called "commercially useless" wave-bands below 200 metres. For some years they had been discussing whether "their" wave-lengths could in fact span the Atlantic after dark. But the hams of those days were badly organised, and it was not until 1920 that such a test actually took place, on the 200 metre wave-length. It was a failure, but in 1921 they tried again, and this time about twenty or so U. S. amateur call-sign letters were heard in Britain, two of them from stations transmitting on less than 100 watts (one-tenth of a kilowatt) power. One station that E. H. Armstrong had helped build in Greenwich, Connecticut, managed to get a complete message over.

Once again the old bogey of the "daylight effect" destroyed what hopes had been raised by this success. Everyone was surprised that 200-metre waves could link the Old World and the New, but nobody believed there was any serious future in a system that worked only after dark and was a complete failure between sunrise and sunset. Hardly anybody considered it even worth investigating, and in fact it was decided to dismantle the Greenwich transmitter, Station IBCG, for this very reason. Hardly anybody, that is, except one notable dissenter. As Armstrong was to write later: "Marconi seems to have been the only man whose imagination was fired by the spanning of the ocean by the stations of the amateurs."

After all, he was the first of their number. In June, 1922, Marconi was again in America to present a technical paper to the American

Institute of Electrical Engineers and the Institute of Radio Engineers in New York. In his strange, half-intuitive way he was moved to tell his audience about his success with the Italian Army directive beams, and with the happy Hendon-Birmingham fifteen-metre radio-telephone link; and he then went on to prophesy the coming radio revolution. Among other things he said: "Short waves have been sadly neglected, especially in regard to directional wireless and radio-telephony. Some years ago, during the war, I could not help feeling we had perhaps got rather in a rut by confining practically all our researches and tests to long waves. I remembered that during my very early experiments as far back as 1895 and 1896, I had obtained some promising results with waves not more than a few inches long .... Progress with long waves was so rapid, so comparatively easy, and so spectacular, that it distracted practically all attention and research from the short waves. This I think was regrettable. There are many problems that can be solved, and most useful results to be obtained by, and only by, the use of short waves ... It may be of historical interest to recall that Sir William Preece described my early tests at a meeting of the British Association for the Advancement of Science, in September, 1896, and also at a lecture he delivered before the Royal Institution in London on

June 4th, 1897. I went into the matter more fully on March 3rd, 1899, in a paper I read before the Institution of Electrical Engineers in London. At that lecture I showed how it was possible, by means of short waves, to project the waves in a beam in one direction only, instead of allowing them to spread all around, in such a way that they could not affect any receiver which happened to be out of the angle of the beam's propagation.

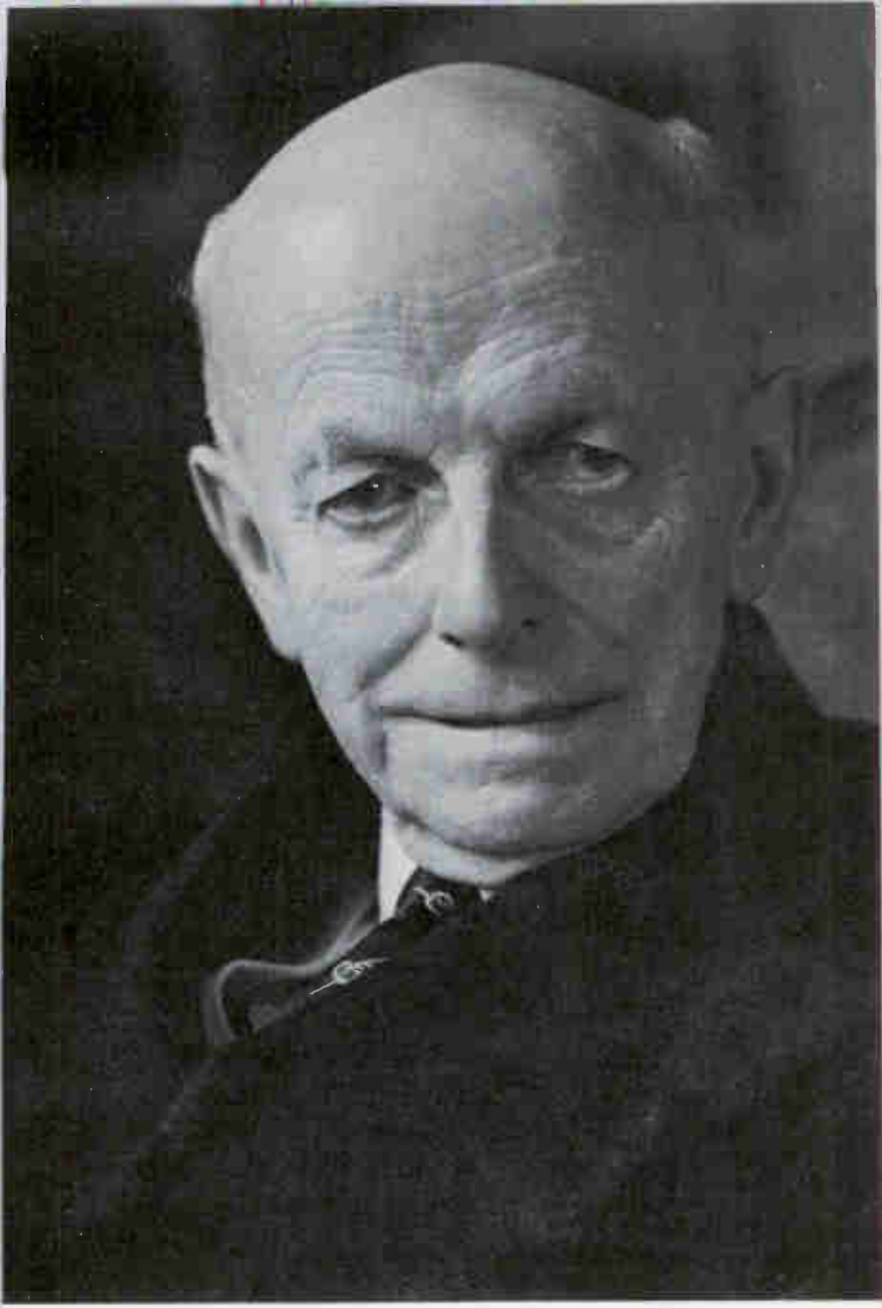
"Since these early tests of more than twenty years ago, practically no research work was carried out or published in regard to short waves, as far as I can ascertain. Research along these lines did not appear easy or promising. The use of reflectors of reasonable dimensions implied the use of waves only a few metres in length, which were difficult to produce. The power that could be utilised in them was small. The investigation of the subject was again taken up by me in 1916 in Italy for certain war purposes. I was valuably assisted by Mr. C. S. Franklin of the British Marconi Company. The work was most interesting. It was like going back to the early days of wireless, when one had a perfectly clear field."

In summing up his address he declared: "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." These were prophetic words indeed in 1922, and as if to back them up, Marconi treated his tough, technically-minded listeners to a superb little display of short wave showmanship. On the stage he had rigged up a miniature transmitter which flung one-metre waves directionally twenty feet across the footlights. A semi-circular, bowl-shaped reflector directed the beam across the stage to the rod aerial, and directly it reached the receiver, a clear-sounding note rang out. When the reflector was turned away from the rod, the signals became almost inaudible, thus revealing the incredibly accurate searchlight effect that could be attained with such apparatus.

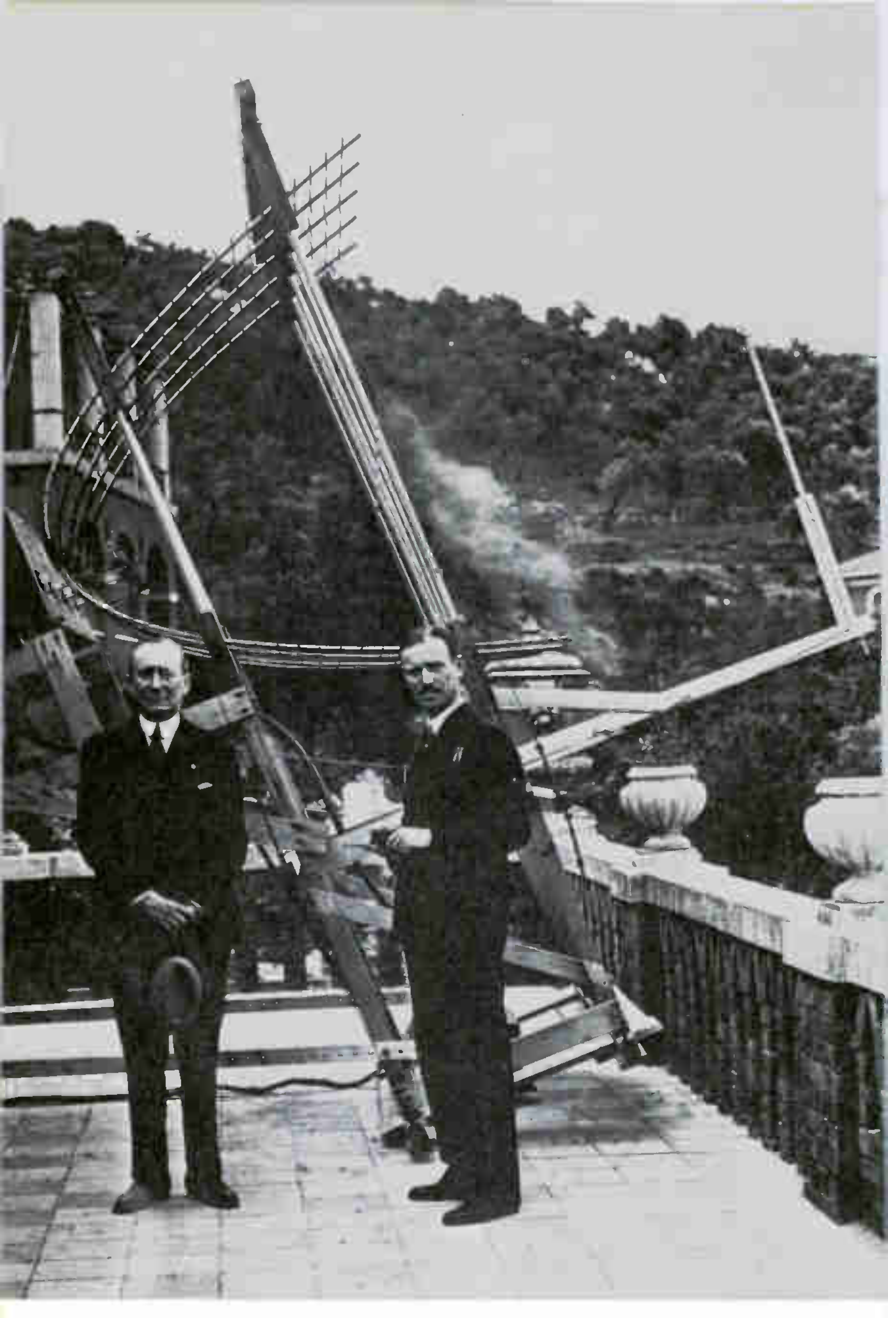
No wonder the audience cheered a slightly nonplussed Marconi to the echo. But he was not yet finished. By way of postscript he added these equally prophetic words: "Before I conclude I should like to refer to another possible application of these waves which, if successful, would be of great value to navigators. As was first shown by Hertz, electric waves can be completely reflected by conducting bodies. In some of my tests I have noticed the effects of reflection and deflection of these waves by metallic objects miles away. It seems to me that it should be possible to design apparatus by means of which a ship could radiate or project a divergent beam of these rays in any desired direction, which rays, if coming across a metallic obstacle, such as another steamer or ship, would be reflected back to a receiver screened from the local transmitter on the sending ship, and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather. One further great advantage of such an arrangement would be that it would be able to give warning of the presence and bearing of ships, even should these ships be unprovided with any kind of radio."

Here, in 1922, the idea of modern radar was clear in his mind, and although he did not in fact live long enough to see it in everyday use, he was to perform some significant experiments in 1934-1935 which paved the way for this now vital factor in navigational safety on sea and in the air.

In 1923 Marconi began his famous series of short wave experiments from the *Elettra*, which he used primarily for receiving, with himself on board cruising at sea and Poldhu used for transmitting, where Franklin had been sent to arrange everything. He had set up at Poldhu a special transmitter to radiate the longest "short" wave for which it was then practicable to build a reflecting beam antenna —ninety-seven metres. The results in every way vindicated his faith in the new method of radio.



27 C. S. Franklin, Marconi's faithful collaborator, who helped him to develop short wave radio after 1924 and also was responsible for the multiple tuner, which would separate the transmission of one station from another on the receiving end.



28 In the early 1930's Marconi returned to experiments with ultra-short radio waves. This aerial and reflector in Italy was used for the transmission of 57-centimetre waves.

He listened to the Poldhu signals as the yacht moved south, finding them extraordinarily good: a range of over 2,500 miles was possible after dark, and about 1,400 miles by day.

Soon Marconi was writing enthusiastically to England: "I have had a most wonderfully successful trip to Cape Verde, in the tropics, and the results have been truly remarkable and well worthwhile (sic) the time and money devoted to them. We can now do distances of 2,500 miles with one-tenth of the power required before, besides being able to send messages in one direction only." Even when the power at Poldhu was reduced to only one kilowatt, its signals could still be heard better than those of the highest-powered trans-oceanic stations in the British Isles. Although the same old "daylight effect" took place, Marconi noticed that the signals lasted for a time after sunrise at Poldhu and became audible again before darkness fell over the Cape Verde Islands.

Marconi intuitively suspected that there was some new and unexplained phenomenon on the short-wave band, and in 1924 he undertook further tests to pursue the matter, especially to compare the ninety-seven metre signals with much shorter ones. In September 1924, he cruised through the Mediterranean to Beirut, where he was astonished to find that the Poldhu signals on only thirty-two metres came through clearly all day—a distance of some 2,400 miles. They were in fact quite as good as the expected after-dark signals, whereas signals sent out from Poldhu on around ninety metres behaved as they had done the previous year at the Cape Verde Islands. Although he still did not fully realise it, he was witnessing the effect of very short waves radiated at a low angle and bouncing back effectively from the F 2 layer of the ionosphere, some 140 to 300 miles above the earth, which they do very successfully in daylight. But as always with him, his practical achievement was way ahead of the scientific theory.

A wave-length of only thirty-two metres, a then unheard-of length of wave, seemed to be about the most effective for long-range work. So the inventor returned once more to England and set about organising world-wide tests. Meanwhile Franklin had perfected his flat type aerial, fed at a number of points from the transmitter instead of only one, with flat reflectors giving a very high degree of concentration of the beam and consequently very high magnification of the amazingly low power used. Marconi notified receiving stations across the world—in the U.S.A., Canada, Australia, Brazil and Argentina— of his intention to transmit thirty-two metre signals with only one kilowatt power behind them from Poldhu at certain times, and he asked that these be listened in for. At once came the favourable reports. In each of these countries the daylight signals came through from Cornwall loud and clear. Even in Australia, most distant of all, they reported successful reception for twenty-three and a half hours out of the twenty-four.

These were truly staggering results, so unbelievable that for a time orthodox scientists could not adjust their theories to catch up with the plain practical achievement. Almost overnight, long-wave transmission became a thing of the past, for here, for the using, was a potential radio link system that would use one-fiftieth of the power, would cost one-twentieth as much as the methods then used and planned for the future. In addition, it would permit telegraphy at three times the previously-used speed. At last, too, the cables were reduced to being a secondary means of communication, since the new transmission speed of some 100 words per minute was far faster than anything they had ever approached.

Marconi and his organisation moved fast. They had to. In 1924 they signed a contract with the British Government to start setting up short wave beam stations to connect England with all parts of the Commonwealth. Marconi must have felt, too, that there was poetic justice in the way the British-owned undersea cable interests, at least, were merged in 1929 with his company's wireless telegraph service into the Cable and Wireless organisation, finally nationalised in 1946. Beam stations sprang up all over the globe, and from that time on, no one ever again considered using long-waves, with their enormously high-powered transmitter, for long-range communication.

Nowadays, all but a tiny proportion of the world's long distance radio communication is carried by wave-lengths under one-quarter of the 200 metre band—once allocated to amateur hobbyists since no one else wanted it. Indeed, the amateurs themselves, with their own specially allotted short wave bands, may often "work" several continents a day without attracting either notice or comment, and some of them make contact with as many as 200 different countries.

Anyone tuning in today to the enormously busy short wave networks on even a simple radio receiver, and hearing the ceaseless stutter of high-speed Morse message-sending and the endless radio telephony that fills the ether every hour of the day and night with interweaving signals, is given fascinating proof of the foresight of Marconi's prophesy. "It is dangerous to put limits on wireless," he once said, and he is daily proved right in the modern world. The "daylight wave," as it became known, was of course only the beginning.

Marconi spent about half of each year in the late 1920s and early 1930s cruising on the *Elettra*, trying to find out more about short waves, more still about the even shorter, or ultra-short waves, and it was only his faltering health that limited his later work. The loyal Franklin continued to support him with various technical improvements like the coaxial feeder for the new small beam aerials, smaller transmitters for short-wave work, short-wave direction-finding equipment for ships and aircraft, and much special gear for the ultra-short waves. In 1932, in Italy, Marconi had got a successful result using a wave only fifty-seven centimeters long, and with a sixty-centimeter wave, he was able to connect the two residences of the Pope with ease. He was especially keen at this time on experimenting with curved wire aerials to project the quasi-optical (under one metre) radio waves, often with the accuracy of a spotlight.

By 1934, his attention had turned to microwave beacons for harbour direction-finding, first, and then for marine navigation. Again the *Elettra* was used for this work and among her other advanced pieces of equipment were two small short-wave outfits described as "twin searchlights" on a single mounting with a dark zone between the two radio beams. Each beam had its own characteristic. The right-hand beam signalled a low-pitched tone on a sixty-centimetre wave, while the left-hand one transmitted a note of much higher pitch. Each note was arranged in exactly the opposite phase of oscillation, so that a "zone of silence" was created in-between the beams, where the two notes cancelled each other out. With this primitive radar apparatus, the *Elettra* was guided into the harbour of Sestri Levante, her bridge screened so that her skipper could not see ahead and make a visual berthing in the usual way. The system was swung from side to side of the harbour entrance like a searchlight trying to pick up something in the dark, the beam sounding its two notes as it directed its waves to left or right. The complementary receiving set was connected to a galvanometer, the dial of which had two halves, one painted red, the other green. All the yacht's captain had to do was to steer his vessel slowly in so that the beam-notes remained silent and the galvanometer needle kept on the central line between its two halves, for this was the hypothetical centre line between the harbour marker buoys. In the event, Captain Lauro berthed her with complete accuracy and safety. One of the many interested experts watching this demonstration was Dr. Arthur H. Compton, and when he saw Marconi use some hand tools to make adjustments to his apparatus he commented to the inventor that obviously he did much of his experimental work with his own hands.

"Yes," replied Marconi, "How else can one think?"

For some time it had been noticed that "shadows" and "reflections" caused by objects in the path of microwaves were often encountered. Then, whilst working on the Vatican microwave set-up, Marconi heard from one of his operators that each day at a fixed time a strange, alien noise came over on his receiver, described as "something like the sizzle produced by someone walking across slushy ground." Sensing yet another new line of research, Marconi set to work to discover the cause of this unusual interference. It did not take him long to find that it was caused by a gardener slowly wheeling his cart past the transmitting room, cutting broadside into the tiny waves. He transferred the idea to a bigger scale, using a car and then a plane in flight, in each case obtaining a clear case of the emitted beam being reflected back to the receiver. If the reflected signals are made to return to the aerial and are then registered, not as odd noises on a loudspeaker but as visual impulses on a cathode ray tube, one has more or less a modern radar set-up.

Marconi was quite fascinated by this new line of enquiry, evolving a rotating radio beam even closer to today's standard equipment, and devising a way whereby range-finding accuracy from ship-to-shore could be increased by measuring the time elapsing between the receipt on board of both radio and sound signals sent out simultaneously. In fact, he concentrated on these directional and navigational aids until 1935, laying the foundation upon which others, notably Sir Robert Watson-Watt, were to build so successfully before and during World War II, during which the widespread practical applications of radar were so helpful to the Allied cause. Indeed, no one in his right mind today would consider undertaking any long or hazardous journey by ship or aircraft not equipped with both radio and radar.

But some experts felt Marconi's diversion from his main microwave studies was unwise, notably Fleming, who declared later: "It was typical of Marconi that, having proved to his own satisfaction that microwaves could be utilised for all manner of purposes, he set about developing and demonstrating some of the practical applications. Among these were specific navigational aids, which imposed a heavy demand upon the services of the *Elettra* and precluded her in further participation in propagation experiments. Had it not been for this, the propagation tests would undoubtedly have continued and our present knowledge of tropospheric mechanisms might well have been much more advanced." Evidently he considered an increased knowledge of ionospheric conditions the more important of the two lines of investigation. On the longest term, with radio working for man in space, he may well be right, but on the shorter term, and not forgetting the inventor's prime concern with safety at sea, he was rather off course.

Towards the end of his life, Marconi's mind was increasingly captured by the possibilities of realizing television by using these very high frequencies. As early as 1927 he had declared: "Short waves cannot but enormously assist in rendering more practical the systems of picture and facsimile transmission, including television.... The science of television is now, I believe, finally emerging from the laboratory." In the very next year, John Logie Baird managed to transmit the flickering, shadowy image of a woman's face across the Atlantic, and not long after that the first colour television was seen. The principles of "scanning," whereby the picture image is electronically reduced to a series of lines, and electrical impulses corresponding to these are generated and transmitted as television signals through the ether (the reverse process taking place in the receiving set), were plainly understood as far back as 1908. But in those days there simply was no technical way of bringing them to proper practical application. Yet from the earliest days, Marconi encouraged his experts to study the possibilities of this even more remarkable offshoot of wireless. As experience in short wave work grew, augmented by Franklin's fundamental contribution to the construction of feeder systems and aerials, the potential of practical television became more evident to him and his workers.

In 1933 he was still considering the possibilities—and the results—for Marconi was never a scientific worker content to let others do what they would with his ideas. He always considered the end results of his work, social, personal, political, even religious. "The secrets of extremely short waves greatly intrigue my curiosity," he told an audience in New York. "The fact that they are not influenced by static is a factor of great importance in television. It makes possible clear, distinct pictures. They will not have the appearance of 'rain' which streaked the early motion pictures. Blank spots and distortions in television pictures are not generally present when ultrashort waves are utilised. We must cheapen the transmission of television pictures, which is at present a rather expensive process. I do not share the opinion that television will kill the motion picture. The relation between television and the films will be the same as exists between wireless and the gramophone. Television and radio will tell us about things that are taking place, but this will not appeal to everyone.... I believe conveyance of information by sound is more important than conveyance by sight. For example, if one wants to sell stock in London he prefers to get the information across the sea as quickly as possible, and doesn't care to see a television picture of the man who takes the order at the other end. We must remember that animals can see, and some have eyes superior to those of man, but man can express thoughts in words and thereby convey information. Speech gives man tremendous power not possessed by animals no matter how sharp their vision. Think what broadcasting has done. A politician can reach a vast audience. What he says is likely to be more important and more appealing than his picture. Broadcasting will survive, despite television. They will supplement each other . . ."

If these prophesies are carefully analysed in the light of what has happened in the thirty-odd years since they were uttered, it will be seen just how profoundly accurate they were. Radio and broadcasting are flourishing throughout the world and show no real signs of dying, in spite of television.

"I believe the next twenty-five years will see developments in wireless quite as important as those marked on the pages of the first quarter of this century. Looking into the future I am confident of the perfection of television or motion pictures by radio." When a questioner tried to outpace even the great man's vision by asking: Have you ever sent messages to other planets? Marconi's humour saved the day: "I've sent lots of messages that never got anywhere," he chuckled. He was to live long enough to see regular television broadcasting become a reality on both sides of the Atlantic, although the vision of radio in space took rather longer. However, he did declare on this same occasion: "I am known as a man who deals in cold scientific facts and practicalities, not in Utopian fantasies. As to the talk of a saturation point—a limit of radio progress—there is no limit to distance, hence there can be no limit to wireless development."

Yet, as with all human endeavour, Marconi's life work was not free of mistakes, of missed chances, of opportunities taken late when they might have been taken early, or even not taken at all. The wonder of his work lies in what he did achieve, nonetheless. Yet with our after-knowledge, it is difficult to resist the temptation to see where he went wrong, in particular his greatest missed chance of all.

For more than twenty years Marconi made it his practice on his very many sea voyages from Europe to America to take along radio receivers to listen in to his various British stations. Yet when he took the *Elettra* across the Atlantic during those fateful days in 1922 it never seems to have occurred to him to take along a fifteen-metre set and listen for Franklin sending from Hendon. If he had done so, sooner or later he would undoubtedly have heard Franklin's signals—and so he would have discovered the daylight wave two years before he actually did so. Of course, it is likewise true that if any radio amateurs in the U.S.A. had thought it worth while to rig up a fifteen-metre receiver and try to pick up those Hendon signals during the daytime, at least one of their number would have been successful and he, not Marconi, would have discovered the daylight wave. But as it happened, no one had the imagination to try: everyone "knew" too much about wave propagation in those days, and it would have only been a madman who would have tried to receive fifteen-metre signals during the daylight across the Atlantic. Yet all the necessary information had been published and the technical equipment then available was adequate. But how could any amateur be expected to do this when the great Marconi himself had also missed the chance?

E. H. Armstrong has admirably summed up Marconi's sterling and unique work for humanity: "In retrospect, no one can regret that it was Marconi who made the great discovery. A reading of his account of his cruises shows that this was no chance discovery, but the result of a careful search by the one man who was able to define the limits of his own knowledge. Marconi set out on a thorough and painstaking exploration of what lay beyond those limits, and his search was rewarded by the success it deserved. To Marconi and those who worked with him goes the credit for the great discovery that put radio in first place in the field of world communication.

"It is seldom given to a man to make two great discoveries, as Marconi did. He created the practical art of radio communication; and a generation later, when the limits of its ability to conquer distance seemed to have been reached, he came along with the discovery that made world-wide radio communication a reality.

"The lesson of his work is clear-cut. He did not unlock the secrets of radio by exercise of some superior reasoning process. He studied the phenomena of radio as he encountered them, with an enquiring and open mind; as he let Nature and his apparatus get the answers for him. The key to this achievement is that he was able to appreciate the limits of his own knowledge, and to doubt what others were ready to accept as dogma. For that rare ability and his infinite perseverance he gained the reward that always awaits the true discoverer—he builded better than he knew."

He did indeed.

# PART III

Chapter 10

# THE STORY OF COMMUNICATIONS

The history of man is the history of communication, from the first grunts of the naked apes presumed to be our distant ancestors to the voice of the astronaut heard live from the moon, over a quarter of a million miles away; from the first signs scrawled on rock or bark to complex radio messages in code; from the harsh commands of prehistoric man to his tribe right down to the present-day suave speech of the statesman seeking to influence a worldwide audience. It has taken man about 500,000 years to reach the stage where instantaneous communication, triumphing over space and therefore over time, could be achieved with the telephone, radio and colour television. And out of all those aeons of time, barely the last one hundred years has been needed to progress from almost no communication to this highly sophisticated stage. For communication now is of little value unless it is instantaneous; it might be as useless one month after the event as information, say from the planet Uranus, if it took hundreds of light years to reach us.

One reason for man's evolution beyond other animals was that he found a means of communicating by voice and gesture. These in fact were the first effective uses of sound and light waves. But both means became ineffective at a distance. Even when he discovered means of amplifiying the human voice—cupped hands, cattle horns, the conch shell or even trumpets, after he had learned to fashion metal—his effective range of communication was increased only by a relatively minor extent. Nor were the visual gestures any better, the visual field often being more limited than the oral. There was nothing for it but to walk or run, depending on the urgency of the communication, until the sender was within hailing or waving distance. The process was speeded up tenfold when man tamed the horse, but it still left man in the situation where imaginative, frustrated souls, harassed by the drawbacks of time and distance, projected their desires for speedier communication into the legend of the magic carpet, or the raven, the crow or the friendly eagle of Norse mythology, the obliging wings of the god Hermes. The invention of the wheel did not prove of immediate benefit.

About 50,000 years B.C. the situation became much more promising with the harnessing of fire to the service of man. Blazing pyres, resin torches and smoke signals added to man's repertoire of visible signals. Metal mirrors are said to have made their appearance in Egypt about 2,850 B.C. and the ancient Egyptians must soon have realised their effectiveness when flashed in the sun over short distances. The Pharos at Alexandria, one of the Seven Wonders of the old world, was built by Ptolemy Philadelphus and its warning beam to ships shone out from 280 B.C. with the most sophisticated system of mirrors and torches until then devised. The first glass mirrors were manufactured in the late thirteenth century A.D. and early in the fourteenth the cannon was invented. Communication over short distances was becoming easier, but not much more reliable than it was a thousand years before.

The first seagoing ships must have appeared in the Mediterranean about 2,750 B.C., and whether they survived or not depended on the clemency of wind or weather, or the skill of the helmsman; for there were no beacons to mark treacherous shoals and hidden rocks. The course was set by the sun, moon and stars and communication between ships or between ships and shore was only possible if they were close enough. It was Sextus Julius Africanus who suggested the idea of semaphore signalling about 200 B.C., and although a primitive form of compass is said to have existed in China as early as 270 A.D., it was well into the ninth century before the Arabs invented the astrolabe. There is proof that the quadrant was in use for navigation in 1456; but man at sea was still isolated from man ashore. If his ship never returned to port it had to be presumed lost.

As man progressed he began to communicate with the written word. Sumerian pictograph writing is the earliest known form, about 4,000 B.C., followed by cuneiform some five hundred years later. The earliest known numerals date from 3,400 B.C. when papyrus and clay tablets were still being used. The Egyptians had mastered a twenty-four letter alphabet in 2,000 B.C., and less than one hundred years later one of the first written stories, *The Story of Sinuhe*, was recorded. For physical communication with other parts of the world there seems to have existed a miniature version of the Suez Canal which the Egyptians dredged out from time to time. That was around 1,360 B.C. A mere sixty-three years before Christ a Roman citizen named Marcus Tullius Tiro is said to have invented a form of shorthand to make communication quicker and easier, and it continued to be used for the next six hundred years. By this time man had pressed the carrier pigeon into service, but otherwise still sent his messages by chariot, horseback, or foot runner, wrapped them around stones and hurled them, or possibly pinned them to arrows and shot them from bows; some communications were scrawled on bark or paper and left in prearranged places, or messages were sometimes conveyed by an agreed arrangement of sticks or stones, or knots in rope as in the case of the Incas of Peru. In Africa messages were relayed by drums.

Nearer to our time men built beacons on the rocks of treacherous coasts to warn ships of danger; Paul Revere made his famous ride in 1775 to warn the colonists that the British were on the march because there just was no other way of sounding the alarm. Captain Frederick Marryat of the Royal Navy invented a system of coloured flags for signalling from ship to shore, but sound signalling was almost entirely restricted to the foghorn and the bell. Thus the end of the eighteenth century arrived without any significant breakthrough by man towards speedy, long-distance communication, although in the *Scots Magazine* there appeared the first glimmer of what was to come.

It was an anonymous article, or at least one bearing only the author's initials, "C.M.," published in an issue in 1753 and entitled, "An Expeditious Method of Conveying Intelligence." It suggested the use of recently-discovered electricity, which in those days was regarded as some sort of fire which travelled along a conductor wire, but which was known even then to have certain properties. The author, whether he was a Scottish doctor named Charles Morrison from nearby Greenock or someone else—by the time interest had grown sufficiently to recall his article it was impossible to establish his identity—suggested that one insulated wire should be set up between points A and B for each letter of the alphabet, or symbol. This presumably would have meant thirty or more lines, if punctuation was to be included. Each wire had its terminal in a pith ball, which was known to be affected by an electric charge, and would lift a piece of paper placed over it if the wire was activated at the sending end by a frictional electric machine. The message would be sent by activating each symbol wire in turn; the monitor at the receiving end would read out each symbol as indicated by the rising paper and an amanuensis would write down the message as it came. But no one rushed to put the anonymous scientist's theory into practice, and it was still far into the next century before the breakthrough came.

When the nineteenth century dawned man knew very little about electricity, and he was further handicapped by the lack of technical means of research into it. He did know that certain phenomena produced a static charge of electricity, and Galvani added to this by showing that "galvanic" or continuously-flowing electric current could be produced. Then the Italian professor Volta produced what was the first electric battery. In the very early part of the century a Bavarian doctor named Samuel Thomas von Sommering and his friend Baron

29 Samuel Finley Breese Morse. Actually a painter, and a good one, Morse did not so much invent the telegraph as develop it. Untrained as a scientist, he had the type of mind necessary to unravel the problems involved and to promote his apparatus once he had shown that it would work.

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GALVANIC AND MAGNETO

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30 An advertisement of 1845 for an electric telegraph system. The early telegraph was of course af great use to railroads and was promoted by them. In England, Cooke and Wheatstone had taken out the first telegraph patent in 1837.

Pawel Lwowitch Schilling worked extensively on the question of communication by electricity and in some places have been credited with the first electro-magnetic telegraph, although their ideas seem never to have been developed to any great extent. In 1816 the British scientist, Sir Francis Ronalds, built a practical working telegraph in the grounds of his Hammersmith home, using frictional electricity rather than the new flowing current, with a system of clocks to translate signals at the receiving end into coherent messages. But like so many others who worked on telegraphic devices, Ronalds was rebuffed when he sought to interest the Government of the day, particularly the Admiralty, in his work.

Over the next two decades names that are now part of the early history of electro-magnetics became known. Oersted's discovery of electro-magnetism came in 1820 and was followed very quickly by the mathematical analysis of it by the French Professor André Marie Ampère, whose name was later given to the unit of electrical current. In 1821 Schweigger developed his "multiplier" and in 1825 William Sturgeon, a British scientist, discovered the electro-magnet, later to be the subject of much development work by the American, Joseph Henry. Two years later Georg Simon Ohm propounded his famous law that the strength of the current varies directly as the electromotive force and inversely as the resistance, and gave his name to the practical unit of resistance in an electrical conductor.

In 1831 Michael Faraday managed to achieve the exact opposite to what Oersted had done and produced electricity by means of a magnet. Work on needle-operating devices to make reception of telegraphed messages simpler was carried out by Sir William Fothergill Cooke and Sir Charles Wheatstone in England, and Carl Friedrich Gauss and Wilhelm Weber in Germany. In 1831 Joseph Henry built an electromagnetic signalling apparatus which caused a bell to be struck by a magnetised iron bar on a pivot.

In 1832 a young American art student named Samuel Finley Breese Morse was returning to the United States on the liner *Sully* after studying painting and architecture in Europe for several years. During the voyage there occurred one of those chance encounters that in history often have produced undreamed-of results. One of Morse's fellow-passengers on the ship was a Dr. Charles Thomas Jackson who, to while away the tedious hours at sea, gave his fellow-passengers an informal lecture on the new wonders of electricity. After explaining the nature of a simple electric current as it was then known, he went on to demonstrate in practical fashion the working of an electromagnet. He showed the fascinated voyagers that when a current is passed through a fine wire coiled round a soft iron bar, the latter instantly becomes a magnet. He further showed that when the current was switched off the magnetic action ceased immediately.

Morse explained years later that the thought at once flashed through his mind that if electricity was clearly not affected by space or distance or time, there was "no reason why intelligence might not be instantaneously transmitted to any distance." The basic desire to communicate quickly with others beyond visual distance had in fact entered Morse's mind long before this. On an earlier visit to England in 1811, feeling cut off from his family in Massachusetts and realising that they must be anxious for news of him at a time when it took many weeks for letters to link Europe and America, he wrote to them, "I wish that in an instant I could communicate the information." Finding the letter years later he scribbled on the margin, "Longing for a telegraph, even in this letter."

The seed planted unsuspectingly by Dr. Jackson in mid-Atlantic took instant root and for the rest of the voyage Morse worked on devising a suitable apparatus for signalling over a distance with the use of electro-magnetism. He filled notebooks with ideas and rough sketches and at once worked out the principles of the signalling scheme that was to develop into the famous and universal dots-and-dashes

Morse code. He even progressed as far as the idea of a pen that moved at the receiving end of the signalling apparatus, actuated by switching the electro-magnet on and off, and writing on a narrow band, or tape, of paper drawn over a spool by clockwork. This of course was the ancestor of the reliable Morse inker used so much by Marconi in his own experiments years later. With that confidence that comes to someone who is certain of the ultimate success of a shatteringly new idea in embryo, Morse said to the captain of the *Sully* before disembarking, "Should you hear of the telegraph one of these days as the wonder of the world, remember the discovery was made on the good ship *Sully*."

But others were also working on similar ideas, all aimed at harnessing the power of electricity for speedy, long-distance communication, and in 1837 Cooke and Wheatstone in England took out the first patent covering communication by electrical means. This included a five-needle apparatus that showed the transmitted letter at the point where two needles crossed, a four-needle version on the same principle, insulation of wires, a method of deflecting telegraph needles by electro-magnetism, and the sounding of alarms in distant places by means of local amplification through a battery. The apparatus, which has been preserved for posterity, is magnificently antique to modern eyes. But at the time it appeared highly involved and complicated, needing six line wires and two keys that had to be manipulated at the one time. Later Cooke developed another version called the "ABC Transmitter," or ABC Dial-Sender, using an apparatus not unlike the modern telephone dial. Wheatstone also took out patents for appliances which printed actual letters at the receiving end.

Morse continued work and by the early 1840s was able to start giving practical demonstrations of the value of his apparatus. By 1842 he managed to get something resembling a message across the Susquehanna River. He tried laying wires under the water, proofing them with hemp soaked in tar and coated with rubber, also using battery-connected lines on both sides of the river which were "earthed" by having their ends in the water. From 1844 onwards he saw his system begin to spread rapidly and successfully throughout the world. In 1845, the year in which Brunel's first iron ocean-going screw steamer *Great Britain* and Samuel Cunard's ships began cutting down the time taken to cross the Atlantic, the first companies were set up in Britain and the United States to exploit electric telegraphy commercially. Morse believed himself to be the inventor of electric telegraphy, but there is much evidence to show that in many cases he took existing ideas and turned them to his own use.

He had to fight many lawsuits before his companies finally were fully recognised, but his code and some of his apparatus was in use from the middle of the last century until the 1920s.

Thus by the middle of the nineteenth century man was well on the way to the goal of instantaneous communication over a distance. Cooke, Wheatstone, Davy, Henry and Morse had all discovered, although separately and for different objects, the principle of the relay, which enabled greater distances to be covered than in the earliest experiments. Public demand for information had shot the capital of the Electrical Telegraph Company in Britain up to a fantastic £800,000. And government departments, which were sceptical at first, were becoming interested. The first recorded case of telegraphy being of assistance to the police was on January 1st, 1845, when the railway station staff at Slough recognised a man wanted for murder, John Tawell, as he got on the train for London. A telegraph message to police at Paddington resulted in his arrest as he stepped from the train there.

In the third quarter of the last century, then, man could send messages almost instantaneously along a wire, to be decoded at the other end, transferred to paper and handed to the recipient. But already he was thinking along the lines of telegraphing the voice rather than a series of symbols. The word "telephone" had been coined nearly two hundred years before, but then it was applied to a megaphone and later to a speaking tube. The actual invention of the telephone dates back to 1667 when man found he could transmit the voice along a string or wire connected to the ends of two tins, the sort of toy that is often used even nowadays by children. An American, Alexander Graham Bell, using electrical knowledge which by this time was fairly advanced, succeeded in 1876—the exact date of the first telephoned conversation was March 10th—in conversing over his rather primitive line with his assistant, Thomas A. Watson. "Mr. Watson, come here: I want you," was the historic first sentence ever to be passed successfully by telephone. And again, like most other inventors, Bell's work finally was only secured after much litigation. Later his primitive apparatus was made more sophisticated by the refinements of Thomas A. Edison's variable-contact carbon transmitter and settled down more or less into the apparatus we know today. Within a very short time nearly two per cent of the population of the United States had his equipment installed. In 1885, even before he had heard of Marconi, Mr. (later Sir) William Preece of the British Post Office was signalling across water to a fair distance by means of electric telegraphy.

But as the captain of the *Sully* may have reflected when Morse's name came to the fore later, the invention of telegraphy, or even the telephone, was of no use to the mariner, since it had to operate between fixed stations. First it went by land line and then by undersea cable, but there was no way by which it could be used by shipping on the high seas, or even by vessels very close to the coast. The telegraph companies also were plagued by the very high cost of erecting and maintaining many hundreds of miles of lines. The time was ripe for some one to discover a way of using electricity for communication over distance without having to have a wire to carry it. It would, virtually and literally, have to be without wires, or "wireless."

Chapter 11

# THOSE WHO PAVED THE WAY

No one will claim that Marconi was the sole inventor of wireless any more than they will dispute his title to being its "father." Like so many things in the field of science, wireless was not invented by any one man but evolved from the work over a long period of many scientists who had dreamed of a system that would permit communication over long distances, without solid connecting links. Many others did vital work, theoretical or practical, which prepared the way for Marconi to examine all the threads, select the ones needed, and use them for practical purposes to set up a workable system of communication without wires. Some of the early pioneers in fact might well have forestalled Marconi if they had not been diverted or discouraged at vital times in their research, or if they could have had Marconi's clear view of the wood unhampered by the trees.

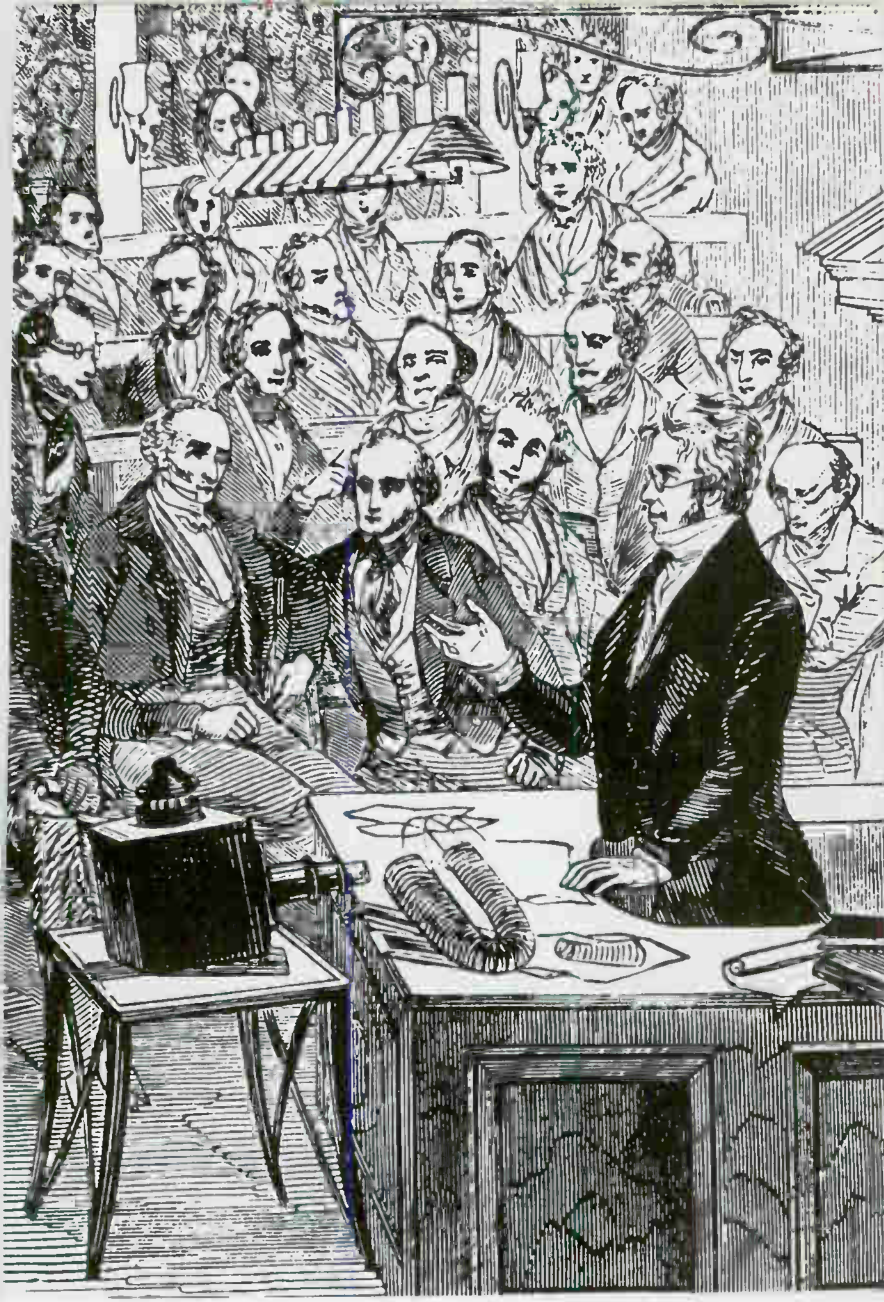
One of the first discoveries in the last century which paved the way towards Marconi's work was that of a young Danish scientist, Hans Christian Oersted, who established the connection between electricity and magnetism. Appointed whilst still a young man to the post of Professor of Physics at the University of Copenhagen, he quickly proved to be a physicist of real genius. Yet he was always a "very unhappy experimenter," not gifted with dextrous hands, a man who met with great physical difficulty every time he wanted to perform even a simple bench experiment. As a result, he needed other people to help him on the practical side of his work. It so happened that he performed the first real experiment in electromagnetism quite by chance.

He was lecturing to his students one day and tried to secure some new form of electric reaction from the basic experiment of placing a wire fed from his galvanic battery vertically and at right angles over the magnetic needle as used in an ordinary compass. Not surprisingly, there was no result, and he proceeded with his set lecture. Afterwards, with his powerful battery still connected to the wire he had used unsuccessfully, he turned to his assistants as the students were dispersing, saying: "Let us now, once, as the battery is in activity, try to place the wire parallel with the needle." This was done, and Professor Oersted was "quite struck with perplexity by seeing the needle making a great oscillation," almost turning round until it was at right angles to its normal north-south position. He then said: "Let us now invert the direction of the current." The helpers reversed the connections on the two poles of his battery and immediately the needle swung the opposite way. It is said that as soon as he realised that he had stumbled on this great discovery of electricity by accident, he was much overcome. He turned to his assistants, visibly shaken, his hands trembling, and invited them to repeat the experiment for themselves.

In July, 1820, Oersted wrote up the results of this chance experiment, setting down the basic principles of electro-magnetism, showing that a wire carrying a current could be made to influence a magnet. As with his previous scientific papers, he wrote in Latin, in the style of the old men of science. This was soon translated into German, and before long an English translation was published in London. Everywhere the report was eagerly read by scientific investigators. In France, Arago and Ampère repeated Oersted's experiment, using a many-coiled wire and developing it further. Ampère in particular was soon well on the way to discovering more basic laws of electro-magnetism, and was the first to extend the Dane's initial work. When the English version of Oersted's account appeared in October 1820, Sir Humphry Davy reacted at once with typical impetuousness. He rushed off to his laboratory at the Royal Institution in London, and started his own similar experiments, but making sure that his young assistant, Michael Faraday, was standing by all the time to help, to verify, and perhaps carry things even further. In the event, Davy did not make any notable advance, but the seed of intense interest had been duly sown in the keen mind of young Faraday, and with Davy's approval, he continued to work on the subject.

Faraday clearly saw that Oersted had demonstrated proof of the definite and hitherto unsuspected link between magnetism and electricity, but he also knew that this was just the beginning. So he vowed to carry these electromagnetic experiments still further, if he could. He would experiment privately, but first he needed to study the subject more fully. With characteristic thoroughness and modesty, Michael Faraday thereupon read every word on the subject he could lay hands on, making himself the best-informed person in the world on every conceivable aspect of electro-magnetism. Then he carefully wrote down all the fruits of this study into his modestly-entitled "Historical Sketch of Electro-Magnetism"—actually a detailed and brilliant resumé of existing knowledge. This "sketch" was in fact so long that it had to be printed in three parts, beginning in September, 1821.

About this same time, his own first major experiments began, and he succeeded in making a fine wire spin merrily round a bar magnet



31 Michael Faraday, the great British scientist, gives one of his Friday Evening Discourses on "Magnetism and Light" at the Royal Institution in 1846. Faraday's basic discoveries in electricity led not only to the generator and electric motor, but also made the telegraph possible.

32 Heinrich Hertz, the German scientist. Building upon the theoretical description of electromagnetism by James Clerk Maxwell, Hertz actually demonstrated the existence of radio waves in 1887.

set upright in a bowl of mercury. In essence, this was the world's first electric motor, but important though this was, it did not exhaust Faraday's interest in the work begun by Oersted. Ten years later, in 1831, he was still as keen as ever to enlarge his knowledge of electro-magnetism, and one day in August of that year he managed to perform the complete reverse of what Oersted had done, in other words to induce a fresh electric current in a dead wire by moving a magnet near to it. Further experiments followed in October, 1831, and Faraday became the first man to produce electricity from magnetism, which he had hoped to do for years. He did this by plunging an ordinary iron bar magnet into and pulling it out from a one-inch thick, six-inch diameter, soft iron coil, wound with long coils of fine copper wire, duly insulated. No battery was used, but each time he moved the magnet into or out of the coil, or solenoid, he got a slight flicker of current registered on his galvanometer, to which his coil was connected. It was not a powerful current, but it was fresh electricity, generated by new means. While the magnet remained stationary inside the coil no current flowed, but directly there was movement in what we now know to be the magnetic field, electricity was induced. This principle of electric induction forms the basis of the modern electric dynamo, whilst from Faraday's earlier work with his coil stemmed the principle of the condenser coil so useful to Marconi and others.

Faraday was very struck by the way electricity clearly moved through space without the aid of wires, and thoughts about this puzzled him for some years to come and meant much more to him than the momentous discoveries he had made, since he never concerned himself with the results of his discoveries, let alone their long-term effects. Instead, he pondered for years just how a weak current could flow from an iron magnet into the unconnected wire of an iron coil. Fifteen years after his induction discovery, when he was resident lecturer at the Royal Institution, he had unexpectedly to fill in one day for a visiting lecturer, a famous scientist of the day who had suddenly developed stage fright! Faraday delivered the announced talk as best he could, but finding himself short of further material and with a few minutes left of the allotted time still in hand, he delivered a separate little talk of his own entitled *Thoughts on Ray Vibrations*. In this he expressed some of the ideas in his mind about the exact way in which electricity is propagated through space.

Later he wrote up a more detailed paper with the same title for the learned *Philosophical Magazine*. Faraday was clearly on the right track, though way ahead of his time. For in 1937, soon after the death of Marconi, when

Sir William Bragg and other scientists of the Royal Society in London opened a mysterious packet of old letters that had lain untouched in the safe there for many years, (some of them oddly marked: "Sealed: Not to be opened at present") they found one written by Faraday back in 1832. In it he said: "I cannot but think that the action of electricity and magnetism is propagated through space in some form of vibration."

The idea of vibration is obviously very close to our more modern concept of waves. Anyway, that article in the *Philosophical Magazine* was read and pondered by a number of learned men and also by a boy of only fifteen named James Clerk Maxwell. Born in Edinburgh in 1831, the year of Faraday's second great discovery, he was something of a child prodigy. He must have been, to be reading that abstruse journal whilst still in his teens, and in fact in the same year he sent a learned paper to the Royal Society of Edinburgh. He was destined from this early age to become a brilliant scientist, and after a spell at Edinburgh University he went to Cambridge where he subsequently won a fellowship at his college. It was then that he was fortunate enough to work for a time with Faraday. Once more the torch of inspiration on electro-magnetic waves, first kindled in Maxwell by Faraday's 1846 article, was passed on to a new and eager mind.

Maxwell was greatly influenced by the older man, and he devoted the rest of his life to the study of electro-magnetic forces, continuing his work when he was appointed to the Cavendish Laboratory at Cambridge, nursery of so many brilliant scientists since.

Maxwell applied his formidable brain to some of Faraday's ideas and suggestions, for he believed that his mentor was right. In the period 1865-1867 Maxwell came up with his great theory of electricity and magnetism, which frightened off many people by the seemingly deliberate obscurity of its manner of presentation, but which we now know was correct in every detail, notably in his conclusion that electro-magnetic waves in fact did exist, that light waves were one form of them, and that they all move at the speed of light. He declared that an oscillating electric field must be accompanied by an equal oscillating magnetic field, and vice versa, and he showed how all these waves are created by electro-magnetism and all possessed different frequencies.

Now the fascinating thing is that Maxwell propounded all these theories in a wholly authoritative way without ever proving any of them in practice. He knew he was correct, for he had proved every single feature by mathematical calculation—not by work at a laboratory bench. He was basically a man of ideas and scientific principles, not a man anxious to make things work in practice. The world of science had to wait another twenty years for Hertz to prove Maxwell's theories.

One who came near to stealing Marconi's thunder years before was Amos Emerson Dolbear, who was appointed Professor of Physics at Tufts College, Boston, in 1874. Of charming personality but incredibly modest, he ranged over the whole scientific field and left his mark on many parts of it, contributing an electric gyroscope, a new system of incandescent lighting and a form of telephone among other things to posterity. When Bell's telephone came into existence Dolbear already held the patent on another form of telephone, which he sold to Western Union and which later was the cause of litigation between Western Union and the Bell Telephone Company. In 1864 he invented a writing telegraph and in 1879 the electrostatic telephone, which was put into operation successfully between London and Manchester and London and Glasgow in 1882.

In the same year he brought out a system for wireless telegraphy and applied for a patent. In part of the application he said, "My invention relates to establishing electric communication between two or more places without the use of a wire or other like conductor: and it consists in connecting the transmitting instrument with a ground the potential of which is considerably above the normal, and a receiving instrument with a ground the potential of which is considerably below the normal, the result being that an impulse from the transmitter sufficient to cause the receiver to give intelligible signals is transmitted through the earth without the need for any circuit, such as has heretofore been deemed essential." Dolbear gave the Society of Telegraph Engineers and Electricians in London an actual demonstration of his invention in March 1882. He explained Bell's telephone, which of course relied on wires for a circuit, and described how he had used a condenser in the receiving instrument. First he demonstrated with the circuit wired, the transmitter being placed in another room and the receiver in the demonstration laboratory. Then he disconnected all the wiring between the transmitter and receiver and asked the president of the society to listen into the receiver while the person in the other room spoke into the transmitter. The president reported that he had heard "perfectly." It was probably the first time the human voice had ever been heard by radio-telephony!

That was sixteen years before Marconi came on the scene and six years before Hertz discovered electro-magnetic waves. If these had been understood at the time and Dolbear had been able to use the knowledge of them it is quite possible that Marconi would have been forestalled. But like so many men with great imagination and inventiveness, Dolbear was impatient with detail and did not have the capacity to develop his ideas in the commercial field; although he regarded it as quite natural that wireless would come, he dropped his line of research when its mechanics became too complex.

Another who came close to developing the first wireless system was Professor David Edward Hughes. Sir Oliver Lodge once described Hughes as "a man who 'thought with his fingers,' who worked with the simplest home-made apparatus—matchboxes and bits of metal stuck together with cobbler's wax and sealing-wax." Hughes' family emigrated to America when he was seven and he received his early education in Bardstown, Virginia. In 1857 he produced a new form of printing telegraph and in London in 1877 he developed a new form of microphone, which took the place of Bell's instrument. Two years later, while experimenting with what he called "aerial" transmission, he set out to discover the true nature of electro-magnetic waves, which seemed to defy any insulation, were invisible and apparently penetrated an unknown distance into space. He succeeded in transmitting signals from one room to another in his Portland Street home, using his microphone as a receiver. When this range proved insufficient for his purpose he set his transmitter going and took his microphone out into the street, still capturing signals up to five hundred yards away.

History does not record what passers-by must have thought of the man wandering aimlessly along the pavement clutching a microphone to his ear! It is now believed that in 1879 Hughes discovered the waves that Hertz later gave his name to, but he met with great incredulity. He arranged a demonstration of his work for the President of the Royal Society, a Mr. Spottiswoode, and two secretaries, Professors Huxley and Sir George Stokes, in February 1880. The experiments were successful and the scientists seemed genuinely impressed; but when it came to the point Stokes refused to accept Hughes' theory, saying all the results achieved could be due to known induction effects. Hughes was so discouraged that he even refused to write a paper on the subject for the Royal Society, and his work might have remained unknown except for Sir William Crookes.

The existence of electro-magnetic waves was finally proved by the brilliant German experimentalist, Heinrich Rudolf Hertz, who died at the early age of thirty-six. Born in Hamburg in 1856, he went to work at the Karlsruhe Polytechnic under the great Helmholtz in 1885. In 1887, at Helmholtz' request, he set out to prove the theories of Maxwell, for whom he had great admiration. He was well aware that thus far Maxwell's assertions lacked any actual physical proof, but he believed they were right. He started from the reasonable assumption that if electro-magnetic waves were like ordinary or real waves, they would in fact behave like such waves in other ways. For instance, they would ripple outwards in concentric rings from the central transmitting point; they would be reflected by suitable surfaces, and would have a fixed and constant length and frequency.

This time, actual experiment revealed what Faraday long before had suspected and what James Clerk Maxwell had deduced to be true by mental calculation. Hertz's apparatus was crude, but it was the true forerunner of the first wireless experiment. It consisted of two large flat coils of wire, each with a narrow gap in them, to both ends of which were fixed large metal knobs, or balls. These were the electrodes. Hertz then built up a powerful electric current from a condenser battery, passing it through one coil, nothing that a spark leapt across the gap between the two balls when the voltage was high enough. He deduced that what really happened was that waves of electrical forces disturbed the air and "oscillated" between the electrodes. He therefore called this side of his apparatus the oscillator, corresponding to the radio transmitter. His identical coil, not connected to the first in any way, he then set up at a little distance, and proved to his satisfaction that a good sparking at the oscillator set up a corresponding spark action at the knobs of the second coil, even when the coils were placed in separate rooms in his laboratory. The second coil he termed the resonator, deducing that it picked up out of space the powerful vibrations, or waves, that were known to exist in theory. From the oscillatory discharge of his first spark, he knew there must radiate outward a potent source of electrical energy. He called it "the outspreading of electric force." When he hung up a polished metal plate opposite his transmitter he proved to his satisfaction that Maxwell's waves, soon to be given his own name, could be readily reflected like ordinary light waves. Hertz also proved that these waves could be diverted, refracted and even polarised just as light waves can, and he was able to measure both the frequency of the oscillations and the length of the waves he had generated, under five metres. They were the first radio waves to be generated by man, and it is difficult to over-estimate the importance of this discovery.

The whole principle of wireless stems from this essential fact that electrical energy can be sent out by these waves without having to send the current itself.

To record the movement of his waves and

their velocity, Hertz had to devise a gadget that would react to their existence. He improved on the earlier discovery by Hughes that if an electric spark functioned near a small glass tube filled with zinc and silver filings, these minute fragments of metal would all cling together to form a definite electrical conductor for just as long as the spark was sustained. By 1890, Edouard Branly, working as a professor of physics at the Catholic University in Paris, took this basic idea a step further and devised his famous coherer as a definite detector of wireless waves. This consisted of a thin glass tube filled with metal filings, which temporarily stuck together, or "cohered," when subjected to electrical impulses, though normally they possessed little cohesion in themselves. At the same time in Britain, Sir Oliver Lodge, who was working on the effects of lightning discharges, devised his form of coherer independently of Branly, found it responded to all forms of electrical charges, and did experimental work on crude wireless telegraphy. The advantage of the filings coherer was that immediately it sensed the incoming electro-magnetic waves, its filings clung together and so completed a circuit through which a local electric current could pass. Once the filings were vibrated mechanically, however, they separated again and the flow of current was broken. So a mechanical tapping device was fitted that caused the filings to decohere at the end of each impulse received and by this means signals from the transmitting end were received accurately.

A Russian scientist was one of the first to see the value of the coherer in distant wireless reception. He was Alexander Stepanovitch Popov, born in the Urals in 1859 and a graduate of the University of St. Petersburg, and the man who, by the time Marconi had started his work, came nearest to emulating him. The year before Marconi went to London, Popov began using the Branly coherer and a Morse printer to study the effects of atmospheric electricity. He improved the coherer by adding an automatic tapping device to restore the metal filings to a loose state after each impulse. In December, 1895 he appended this note to a paper of the same year on his work: "I entertain the hope that when my apparatus is perfected it will be applicable to the transmission of signals to a distance by means of rapid electric vibrations—as soon as a sufficiently powerful generator of these vibrations is discovered."

Soviet communist propagandists in their chauvinism have always claimed that Popov was the father of radio. But there has never been any solid proof of claims that Popov actually demonstrated wireless reception publicly at the University of St. Petersburg in

April, 1895. There is no doubt that a lot of his work ran parallel with that of Marconi, but Popov himself seems to have admitted that he was behind Marconi for, as we have seen, no one seems to have been more eager to credit Marconi with the main role than Popov himself.

Other people were studying the Hertzian waves, notably Professor Righi in Italy; Preece was aware of their existence, and in 1894 Sir Oliver Lodge had perfected the equipment needed to demonstrate a rough form of wireless telegraphy up to about 150 yards. But Lodge was working towards another goal altogether, the further examination of light waves and how they differed from electromagnetic waves. In 1893 the Hungarian-born American inventor, Nikola Tesla, developed a system for wireless telegraphy, But the truth seems to be that by the time Marconi came on the scene everyone in the scientific world was floundering in the then existing scientific knowledge of the subject without making any forward progress into the practical realm. And if Marconi had lacked the special vision and foresight that had been his since his adolescent days, he might not have got any further either.

As G.R.M. Garratt says: "Of all those who had blazed the trail he alone had the vision to see the practical application. Where others had seen only a new and interesting phenomenon, Marconi saw its practical utility." It was always the practical side, not the theory, that interested him and spurred him on. Indeed he always hoped secretly to be able to demolish existing theory as propounded by the scientists with practical proof of something different, and the more different the better; as we have seen he did it on several spectacular occasions. It is clear that if he had been hidebound by scientific tradition himself, trained to believe that all matter obeys known laws, he would never have achieved the birth of a new age for mankind.

Fortunately, as it happened, Marconi was less of a scientist and more of a true discoverer, a man lacking orthodox scientific training and doubtless more than a little impatient at having had to be subjected to it at all, yet naturally endowed with an enquiring mind and questing spirit. In many ways he was one of the last of that noble race, the non-scientific discoverers, as he was one of the last of the great amateur inventors. Today it would be inconceivable for any one man to push forward any comparable scientific discovery without good background knowledge in science and mathematics and practical scientific training. So in that sense, as in many others, Marconi remains a unique figure.

## Chapter 12

# WORLD WITHOUT RADIO

Radio and television today have become so much a part of our everyday scene that we tend to overlook the significance of the original achievements of Marconi, who opened up the way both for them and for their related scientific developments. So one way of appreciating Marconi's work would be to try to imagine—hard as that might be—what the world would be like today without the use of radio waves in their many manifestations. The more the imagination is stretched the harder it becomes to visualise civilisation bereft of all his discoveries, and it would be exceedingly hard to apply the adjective "modern" to such a world.

Try to think, for instance, of a home without a radio or television set. They are virtually as much a part of the basic furnishing as a bed or a bath. Without them we would be back in the days of the telephone, the simple telegraph or mail as means of communication, the newspaper or the cinema newsreel to tell us what is going on in the world, and the drawing-room concert, the music hall or the cinema for our entertainment. From the time Marconi placed it on a firm footing about half a century ago and from the first known broadcast of a concert—from a garden fete in Hampstead—in 1922, radio on a general broadcasting basis has made steady progress. Britain first started handing out broadcasting licences on a very sparing basis, fearing the ether might become overloaded, and finally decided that broadcasting generally should be in the hands of a public corporation. The B.B.C. received its first charter in 1927 and ever since has handled sound broadcasting in the United Kingdom, maintaining a great measure of independence from political interference and trying to steer a non-partisan, centre course between opposing lines of thinking. It has always been strictly non-commercial. In the United States the opposite system was adopted from the beginning, making advertising pay for the cost of developing broadcasting facilities. In countries like Canada and Australia and some others the two systems are allowed to exist side by side, while in some countries broadcasting is in the hands of the government and often is used for political propaganda purposes. By 1930 most countries had some sort of broadcasting system, whereas by the early 1960s the total number of larger broadcasting stations throughout the world had risen to more than 10,000, grouped into a world organisation for purposes of control of wave-lengths and other aspects of broadcasting order. The total number of receiving sets today is not known but is estimated at hundreds of millions.

For countless of these millions of listeners radio is a boon and a blessing, a comfort, a release from the worries of modern-day high-pressure living at the turn of a switch. For the average housewife it is a musical accompaniment to the chores of the day, for the many lonely people in the world it is a deliverance from despair. Without it hospital patients in most parts of the world might lie worrying about their pains instead of listening to cheerful voices; others at home, the "shut-in" the sick or the elderly might live out their lives uncheered by this contact with the outside world. The great humanitarian solace brought by "wireless for the blind" would be unknown. There would be no reassuring radio-telephone link-ups with loved ones on the other side of the world, no cheerful messages of the type pased on in some programmes.

In terms of education absence of radio and television would have far-reaching results. Many programmes on both media today are instructive, either by chance or design, to the adult listener. They tell the handyman how to tackle a job, the housewife about cooking she may not know, and a thousand other things. But there are also many programmes in many countries aimed at providing schooling on a full-time basis for children, like those in the outback of Australia or the remote regions of the Soviet Union, or for instance for children on Dutch barges who rarely stay in the same place long enough to attend a fixed school. There are "universities of the air" catering for further education, and a great many closed-circuit television systems in use in schools themselves. But man also learns, no matter what stage of education he has reached, by listening and watching and even everyday entertainment programmes may teach him something.

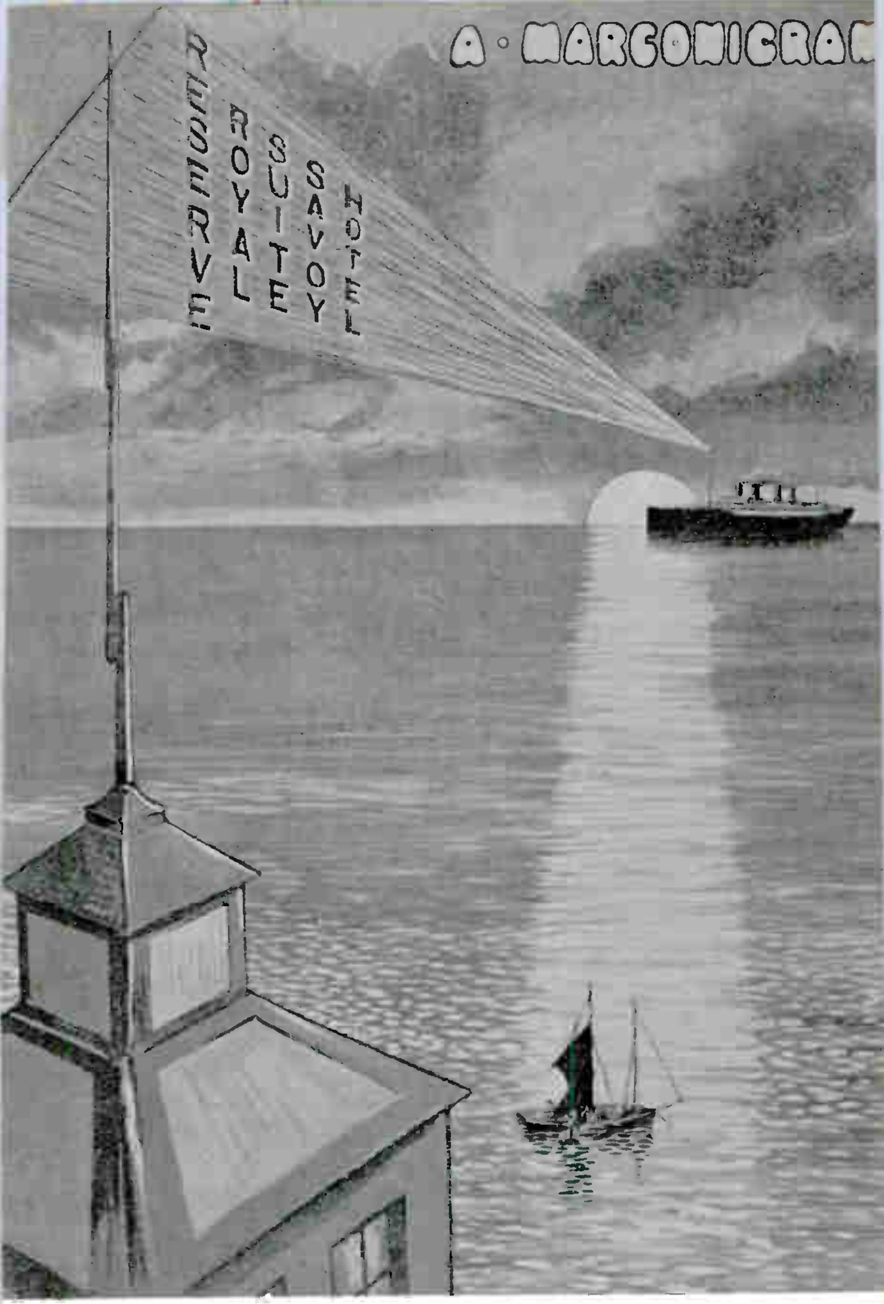
The world of music would be in a far sorrier plight today if radio had never existed. About the time broadcasting was coming into vogue, music was already on the decline due to a number of contributing factors: the cinema had begun to provide light entertainment, the older and more gracious manner of living and making one's own music at home was on the wane because people no longer had the means they enjoyed before the war. Since music was one of the easiest ways of filling in broadcasting time the radio restored it to popularity until today it is probably in greater vogue than ever before, whether it be classical, jazz, or modern pop. Without radio it is highly unlikely that the gramophone record would ever have reached the fantastic popularity it has today.

There would be virtually no such thing as an SOS message to help those in peril on the sea. Shipping would be almost completely at the mercy of the elements again, having to rely on visual or aural warnings from lighthouses, lightships and buoys. Fog would be once again one of the deadliest enemies, without radar, radio beacons and other homing devices, and marine navigation back almost to the days of Columbus. Sailors and sea passengers everywhere would be cut off for days, maybe weeks on end, and the trials of loneliness, homesickness and terrible isolation once more would be their normal lot. Air-sea rescues would be almost unheard-of, nor would there be the possibility of speedy calls for help over long distances, no swift call for aid for special emergencies like earthquakes, tornadoes or floods. Nor would it be likely that serum could be rushed to some remote corner of the earth to save a life or lives. There could be no question of lowering a television camera down a mineshaft to help locate survivors below and without radio Australia's Dr. Flinn would never even have thought of the first "Flying Doctor" service to save lives in the bush.

Air travel itself would most likely be on a very reduced scale since it is hard to see what might have been able to take the place of radio in operating large fleets of commercial airliners. Most likely flying an aircraft would be right back in the days of the daredevil pilot, the crazy adventurer. Landing, especially in fog or other bad weather conditions, would be an immensely hazardous business without the comforting "talk-down" support, and things like automatic pilots, foolproof navigation and supersonic flight would probably be quite impossible. Fliers who survived the hazards of flying without radio, also, would get no help from the ground if they lost their way; air-drops like those in Normandy, Arnhem or Korea and Viet Nam would have been impossible.

Most people would probably carry umbrellas daily since weather forecasting would be relegated to the old days where the state of the meteorologist's corn was about as reliable a guide as any. There would be no weather ships to radio information on which forecasts could be made, no satellites to report back to earth about longer-range prospects, no friendly faces on television to point out, with maps, what was likely to be happening with the weather fronts for the next day or so. Radar meteorology, a sophisticated modern use of radar to detect formations, would not exist. Nor would radio astronomy have been of such invaluable help in complementing the findings of optical astronomy about the universe around us.

Police would be greatly hampered in their duties, for radio now has become of prime im-




33 An advertisement for a "Marconigram." In 1906, when this advertisement was put out, the most immediate and most startling advantage of Marconi's wireless was to communicate with ships at sea. Today, radio communications permeate our world and reach to the moon and beyond.

portance both in preventing and solving crime, in traffic control and in maintaining law and order generally. The first known case of wireless being used in crime was in 1910, when a message crackled out over the ether from England to a steamer then nearing Quebec. It informed the captain that among his passengers was one Hawley Harvey Crippen and that he was wanted for the murder of his wife, known on the stage as Belle Elmore. Crippen, having fallen in love with a young stage artiste, Ethel le Neve, killed his wife and disposed of her body. With Ethel disguised as a young boy, they took the steamer for Canada but police had already found part of Mrs. Crippen's body and there was no doubt of Crippen's guilt. He was arrested and taken back to England, sentenced to death and executed a few months later.

Since those earliest days radio has become an integral part of police equipment, with constant transmissions between police stations and roving squad cars, between helicopters and ground stations for traffic control, and even with special television cameras and stations for control of major highways. Even the ordinary policeman in most places now has his own pocket-sized two-way radio to keep him in touch with headquarters. And banks and stores have hidden television cameras to trap bandits and shoplifters.

Espionage, whether international or in the field of industry, has come to rely heavily on highly-developed appliances ranging down to the size almost of a pinhead which can be hidden and set to transmit conversations. Some are so sensitive as to be able to pick up and transmit conversations within a wide radius to receiving stations hundreds of yards away, or to recorders which register the conversation for later transcription. The deadly threat of such devices, without which Ian Fleming's James Bond would have been a pretty dull fellow, is so great that some countries have outlawed them.

Without radio there would be no comradely world of "hams," the radio amateurs who form perhaps one of the nearest approaches yet to the idea of "one world," with their friendly global conversations in radiotelephony or Morse making a mockery of frontiers and ideological curtains. Sport would probably be severely limited without the great international interest engendered nowadays by the possibility of seeing live contests that spill over into healthy goodwill from one nation to another. Sports commentaries as such would be unknown and many an argument about a scored or missed goal would go down in history unresolved but for the possibility of turning back the video tape and showing it again in slow motion.

Perhaps hardest of all to imagine is a world without television and its many influences. The "television personality" of today would still be totally unknown, his well-loved or thoroughly loathed characteristics lost to the world; and in many cases millions of people would be the losers, for some personalities are eagerly awaited and watched every week. State or other important occasions would be reduced to being reported by the printed word and newspictures, or perhaps in next week's news gazette at the cinema, without the accompanying dignity of a Dimbleby or the authoritive commentary of a Cronkite. The entertainment business itself might well be still at music-hall and summer show level.

In industry, development of radio and television and associated equipment has meant the rise of one of the greatest employment factors of all time. It is impossible to estimate how many people throughout the world are engaged in the business of sound and television broadcasting, its affiliated technical, administrative, writing, producing and acting services, and in the production, sale and distribution and maintenance of radio and television sets, equipment for more advanced aspects of radio like microwave installations, ultrasonic cleaners, and defence installations, as well as equipment concerned with space travel and investigation. What would these millions have become without radio?

The fighting forces of the world would have to do battle with communications systems simpler than those used in the Boer War; not for them the advantages of intercontinental ballistic missiles, air-to-land, land-to-land, anti-missile or anti-anti-anti-missile missiles. Their generals could not easily summon up reserves, deploy their forces, or be protected from attack by early warning systems.

Nor would the modern day vocabulary contain words like microphone, megacycle, condenser, superheterodyne, microwave, frequency-modulation, ultra-high frequency, video-amplifier, semi-conductor, radiotelemetry, modulations and bandwidths, resonators and masers.

Imagine the last fifty years without having heard or seen the mad but mesmeric rantings of Hitler, the rallying rhetoric of Churchill, the friendly fireside chats of Roosevelt, the snarlings of Stalin, the pathetic assurances of Chamberlain, the perorations of de Gaulle or the bright hopefulness of John F. Kennedy. We would have had to wait until the next day to know that Jack Ruby had shot Lee Harvey Oswald, Kennedy's assassin, instead of seeing it happen before our eyes. News of all kinds would take longer to reach us, and memorable events would have lost in their effect on us, for the printed word is no match for the visual image of actuality.

One of the most important aspects of radio and television is their impact as mass media on the future of mankind. The power of a television broadcast watched by millions of people is incalculable; even a sound radio broadcast may have a fantastic propaganda effect. The Russians were the first to realise this and used radio as early as the 1920s for propaganda purposes. The idea was picked up by Fascist Italy and then by Hitler's Germany. It is even questionable whether Hitler might have gained such a hold over Germany without this powerful weapon. The Allies quickly realised its value as an arm of psychological warfare in World War II; but its value as a weapon of truth and comfort to those behind the lines or in enemy-occupied countries was as great or greater than its value as an instrument for spreading alarm and despondency among the enemy.

The time is rapidly approaching now where any statesman or politican has little hope of success unless he has a good "television image." Those who have not, take lessons from professionals to improve that image, for the effect of a single speech on television is as great as a thousand speeches without this instrument. If the speaker comes over badly, he could ruin his whole political career, astute as he might be off-screen. Even kings and queens are coached, for with nearly 100 million television sets throught the world, and simplified means of transmission to all countries, they could be seen in one appearance by nearly half the world and therefore everything must be right. With such frightening power now vested in television it will have to be left to historians of the future to decide whether its influence has been good or bad and to what extent it has affected the lives of the public, and what impact it may have on future generations.

## Chapter 13

# ON TO INFINITY

Apart from the immensity of Marconi's achievements in his own right, what cannot be over-stressed is the impetus his work and successes gave to others in his and closely related fields. In the narrative of his work we have already seen how men like De Forest, Franklin and Fleming were encouraged by Marconi's own break-throughs to develop and add their own particular lines of thought and discovery to the general progress of radio. Clearly Fleming would never have been spurred on to devise the thermionic valve, with all its far-reaching effects upon radio transmission and reception then and since, without Marconi's shining example and inspiration. In Fleming's particular case, he was engaged and consulted by Marconi many times for technical aid, especially in the early days of Poldhu, and as early as 1899 was inspired to forecast the whole future of radio, when he lectured on the progress of the new science to the learned figures of the British Association at Dover. Similarly, Lee De Forest would not have considered it worth bothering to perfect the valve by making it a triode had he not been convinced that Marconi's work had an immense future. The slowness with which some of these related inventions were taken up by Marconi as well as by others in no way invalidates this general principle of the major pioneer inspiring and giving the necessary impetus to the minor figures of radio's steady development.

The same thing remains true with later figures of striking importance.

The notion of seeing at a distance, not called television until well into the present century, was in fact in many men's minds as far back as 1880 and possibly even earlier, when a number of pioneers in Britain, France and America had worked out a variety of methods under an equal variety of names—"telectroscope," "seeing by telegraph," "electric telescope," "picture telegraph" and "photo-telegraphy" among them. Hard though it may be to believe today, this particular form of communication excited many inventors much more than wireless itself, not then perfected at all. As Oliver Lodge pointed out, scientists generally were much more interested in the phenomena of light and vision (things they believed they already knew a lot about) than they were in radio waves and hearing (which brought in intangible forces very far from being fully understood then, or indeed for some years afterwards). Consequently, many of the early ideas for TV were based on light processes and the known fact of "persistence of vision," as exploited by the moving picture, and not very much on the actual transmission of pictures through the ether by wireless waves.

This was understandable, and so it was not until the early years of the present century, after Marconi had shown radio transmission over considerable distances to be a practical possibility, that TV-obsessed inventors saw the answer. It was to combine the two systems, the light processes (soon given new impetus by the perfection of the cathode ray tube, first devised by Crookes as early as 1878, fully developed in 1897 by Marconi's Nobel co-prize-winner, Karl Braun, and first suggested—for television purposes in 1907 by the Russian scientist Boris Rosing), with the etheric transmission made possible by radio development. The firmly entrenched use of wireless, by about 1908, gave the television pioneers fresh hope—some of it ill-founded. In 1908, for instance, a French inventor named Armengaud said he "firmly believed that within a year, as a consequence of the advance already made by his apparatus, we shall be watching each other over distances of hundreds of miles apart."

By 1911, A.A. Campbell Swinton, the brilliant English electrical engineer who had already played a vital part in the Marconi story by introducing Marconi to Preece back in 1896, had prophesied that the future of TV lay not in the revolving mechanical scanning discs devised by Nipkow and others but in the exclusive use of cathode ray tubes for this purpose in both the transmitter and the receiver. In short, he foretold that scanning would be achieved electronically. His prophesy came true, even though it took nearly thirty years to achieve. The reason for this was that World War I intervened, and although that conflict lent enormous impetus to radio, especially for short-range links, it all but killed television experimentation. TV had not progressed sufficiently far to be of obvious value in wartime, and so the time and money necessary for its continuing research were diverted elsewhere. It is probably true to say that had there been no war from 1914 to 1918, the world would have come to know television, as well as radio broadcasting, during the 1920s.

That television came at all is clearly due to the efforts of many men, Ayrton and Perry, Senlac, Willoughby Smith, Nipkow, Weiller, Crookes, Rosing, Braun, Campbell Swinton, Bell and Jenkins, to name only a round dozen. This by no means exhaustive list excludes Marconi himself and also the one man who undoubtedly did more than any of the others to make television a practical reality, as Marconi had done for radio. This was John Logie Baird. Whilst it would be false to suggest that all through the wayward and undisciplined genius of this strange Scottish inventor, who was the first to push the viewable TV picture over into practicality, there shone like a glowing inspiration the vision of Guglielmo Marconi, the work of these two vastly contrasting men formed part of a quite natural progression. And it is true to say that during his early years as an engineering student at Glasgow University, about 1912, Baird was greatly impressed with the progress that electrical engineering had by then achieved, in particular Marconi's feat of putting wireless permanently on the world map.

It was then that he first toyed with the idea of "seeing by wireless," as he later came to describe it. Of course, this was by then not a very new or original idea, and Baird did nothing about it at that time beyond interesting himself in the possibilities. It was not until 1923, when he was an almost penniless failed inventor of thirty-five, that he took his fateful walk along the Sussex chalk cliffs near Hastings with his sceptical old school friend, Guy "Mephy" Robertson, and suddenly recalled his earlier interest in the potentialities of seeing by electrical means at a distance. He decided there and then that this was to be his real life work. Returning to his bedroom, he started right away to work on his first prototype model equipment, beginning as crudely as Marconi had done nearly thirty years before at the Villa Grifone. He gathered together simple batteries and valves, an old electric fan motor from a junk heap, a tea chest and a biscuit tin, a hat box, some wire, darning needles, a bulls-eye lens, sealing-wax and glue. "You don't know what you're attempting," Robertson told him. "You'll never succeed."

But although, in the end, Baird considered himself a failure in that his final system was passed over by the B.B.C. in 1937 in favour of the far superior Marconi-E.M.I. system (ironically perfected by Marconi engineers at Chelmsford under the direction of R. J. Kemp), and his earlier brilliance was suddenly eclipsed, by then television had come to stay, and he had been largely responsible. Through him, more than anyone else, TV broadcasting was finally taken seriously as a practical possibility; and although his own mechanically-scanned system was bound to be superseded in favour of the higher-definition picture achieved by his competitors, he alone must take credit, not as the "inventor" of television (there is in fact no such person), but as the man who first made it work.

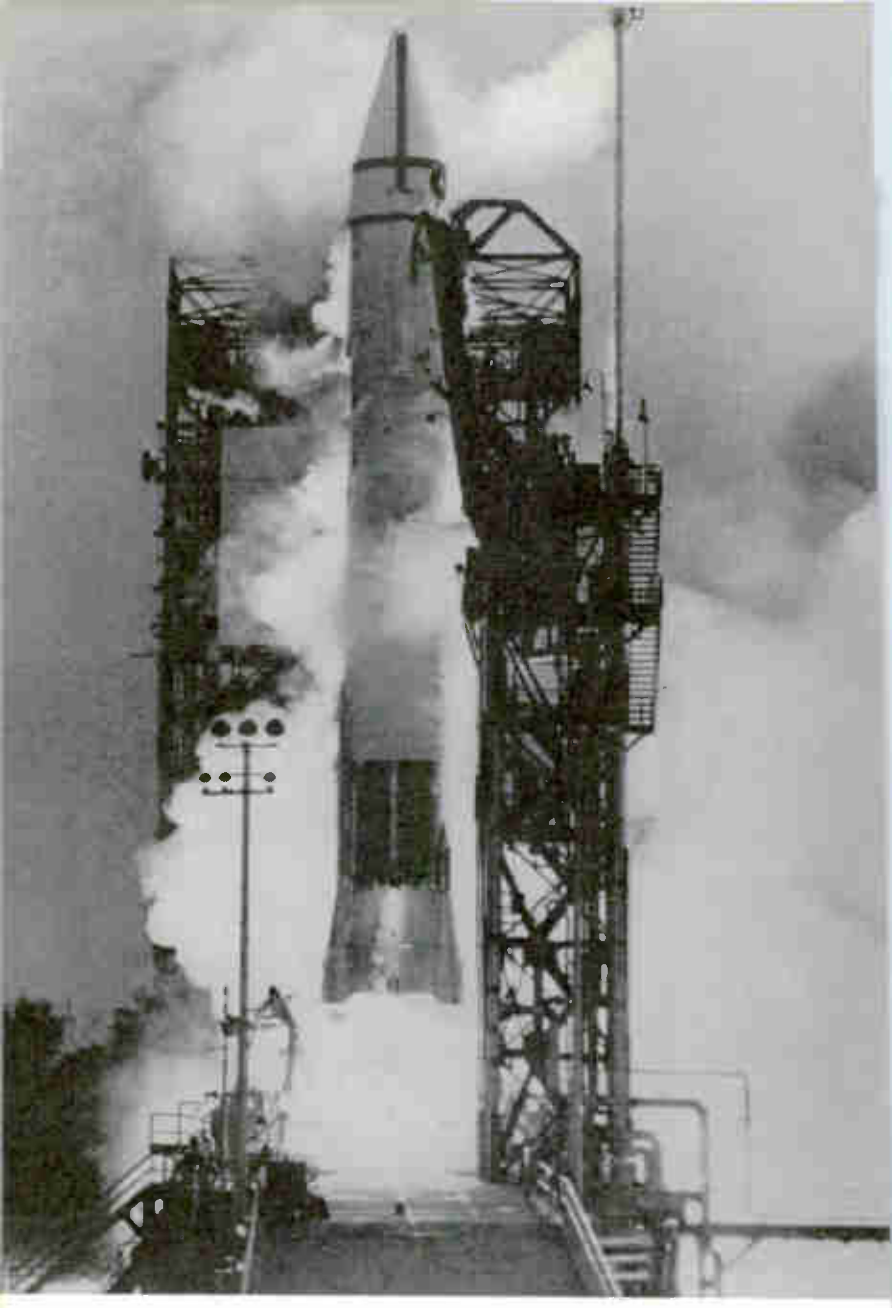
In this respect, as in some others, there is a parallel between Marconi and Baird. Both were scientifically ill-trained, both were essentially amateur inventors, both took the known principles discovered by others and gave them practical applications. Both, too, worked on techniques that soon became completely out of date. Baird's system of television was far from perfect, and he was too stubborn in his refusal to recognise the advantages of the all-electronic system. But that in no way denigrates his achievement as the first man to produce a really recognisable TV picture (in 1926), any more than the vast difference between modern radio apparatus and Marconi's first spark transmitter and filings coherer lessens *his* superb achievement.

Marconi himself showed much interest in the development of television, the eventual success of which he never doubted, but in the main he was content, rather than to experiment there himself, to let his own achievement and example inspire others to follow on in that particularly specialised field. Nevertheless, as we have seen, he was well aware that his own work on very short waves had made practical television broadcasting come more rapidly than it might otherwise have done.

Similarly with the inventor of radar, Sir Robert Watson-Watt. As a young man he started to study heavy electrical engineering but switched to radio-telegraphy instead, and during World War I was employed by the British Government as a weather-man, one of whose jobs was to try and give accurate forecasts of approaching thunderstorms to airmen of the Royal Flying Corps (predecessor of the Royal Air Force). He had long been interested in the causes of atmospherics, the curse of all wireless reception: he knew most of these annoying interference noises were caused by lightning flashes, but he felt some might be produced by other means, although very little was known about them. In 1916 he had perfected a new way of registering distant lightning flashes on a cathode ray tube, and after the war he had grown so interested in this field of research that he turned down an offer made to him by the Armistice Commission to visit Germany to study weather problems. Instead, he worked for the government on further problems of atmospherics, erecting a large directional aerial on a Scottish hilltop to trace the exact direction from whence these disturbances came. He was also drawn into the research work being undertaken by the British scientists Appleton and Barnet into the height of the ionosphere layers, using radio techniques.

These two brilliant investigators sent up continuous radio waves into the ionosphere and made intricate measurements to determine the exact height of the reflecting layers. They noticed that when an ordinary aircraft flew past while they were working their measurements were badly upset. This disturbance they regarded as an unavoidable nuisance, much as radio operators had regarded atmospherics

34 Television cameras in place in Whitehall, London, in 1946. Although television did not become a commercial possibility until after World War II, it was actually developed before the war. Marconi, always alert to new possibilities, foresaw the potential of television in the 1920's.



35 A Surveyor 4 moon probe takes off from Cape Kennedy, Florida in 1967. Without radio communications the landing of the first men on the moon and the probes of Mars and Venus would not be possible. Like most basic inventions, Marconi's wireless has had applications that even Marconi himself might not have foreseen.

butting in on their reception for the past two decades. Watson-Watt, however, saw further. He realised that such interference might hamper ionospheric research, but equally it might well prove useful for the deliberate location of flying aeroplanes, which had hitherto been detected only by sight or sound. Between 1926 and 1931 he experimented in earnest with the pulse method of echo-detection of planes, recording the so-called "nuisance echoes" on a cathode ray tube screen. Radar had been born. Watson-Watt was fortunate in persuading the British Government of the usefulness of his discovery, and he was given every assistance in secret to perfect his system for the radio location of flying aircraft, which he fortunately did before German aircraft began flying over England in 1940. The rest is history; but once again the direct inspiration, as well as the practical means of development, sprang from Marconi's radio.

Lastly, the field in which the development of radio still has furthest to go, in every sense —space travel: if the Germans were mercifully way behind British scientists in the race for radar, they were far ahead of the rest of the world in two other fields, soon to be vital: jet-propulsion for rockets, and radio control of flying mechanisms. Both these were fields in which British and other scientists had worked prior to 1939, but the Germans had made the most progress. They had produced effective rockets and also pilotless flying weapons. In addition, they had mastered the art of controlling such mechanisms from the ground by radio, starting with model aeroplanes and expanding their techniques to full-size aircraft.

When they came to bombard Britain with their two much-vaunted "secret weapons," the knowledge and skill they had developed during the 1930s were combined—although not at first. For the V.l. or flying-bomb, the pilotless jet-propelled long-range bombardment weapon, was not generally controlled or directed by radio, being merely launched from a long sloping platform that faced the target area and fitted with a time-device that cut out its engine after 100 or 150 miles had been traversed, so that it dived earthwards as a destructive weapon. But the real brain-child of German rocket expert Wernher von Braun (now working for the Americans), the V.2. rocket, a 12½-ton long-range projectile (some 2,000 of which fell silently on London and southern England between September, 1944 and the end of the war with Germany seven months later), *was* radio-controlled for the first part of its flight. If the war had lasted, von Braun undoubtedly would have been able to control them by radio for the whole of their flight, pin-pointing them accurately onto specific targets.

Because of radio, which provided the means of control and direction, von Braun's rocket became the prototype not only of today's military guided missiles in all their forms, but also of the booster rocket on which space travel depends. Von Braun and some of his colleagues went to the United States after the war ended, while some other German scientists went to work for the Soviet Union. In both countries work went ahead to develop means of putting satellites into orbit round the earth and then to develop vehicles which could thrust far out into space. Again there was little point in firing rockets out into the space between the earth and other planets, a space believed to consist of about one atom of matter, mostly hydrogen, per cubic centimetre, unless it was possible to have information radioed back to earth. The U.S. WAC Corporal was launched in 1945; the Russians won the race into orbit with their first Sputnik on October 4th, 1957 and the Americans were not long in following up with Explorer, Vanguard and other projects.

In 1954 the U.S. National Aeronautics and Space Administration was allocated 331 million dollars for space exploration; in 1954 it had risen to a massive 5,000 million and the amount expended by NASA by the time man reached the moon is estimated at somewhere around 25,000 million dollars. The Soviet Union's figures for equivalent space development have never been fully published, but in terms of manpower and money they must be as colossal. Whether prompted by the urge that he might one day control the earth from space by military means, or simply by the urge to explore space, man finally ventured out into space himself, knowing that he could remain in communication with his own planet through the radio system which Marconi had put firmly into existence at the beginning of the century, and that it would bring him safely back. Compared with the long history of the development of communications it was virtually no time before he reached the moon; and there was still an infinity of space to explore. Not only did he continue to learn more about the universe but he was able to use satellites and radio to bring man closer to his fellows on earth through live television—a long step from the day Marconi bridged the Atlantic by radio.

As we watch an astronaut actually landing on the moon and conversing with earth 250,000 miles away as if he were in the same room, we suddenly feel humble. It brings home to us forcefully how radio has surely changed the world more than any other single innovation; and it is against this fact that posterity must measure the full significance of Guglielmo Marconi's work. Yet for all he achieved, Marconi was imbued with impressive humanity and salutary humility. Just as he is accepted as one of the last great amateurs of science, so some might consider him also to represent the last notable example of the exercise of the human spirit so necessary in any field of scientific endeavour—and never more so than today. He never forgot that people must always come first and science second, and so he adapted science, sometimes in an unorthodox fashion, to make people safer, happier, less lonely, better informed, more prosperous. And every single person today, scientist or layman, can still learn something from the significantly humble, but also vastly prophetic words he once uttered in a rare moment of self-revelation:

> The more a man bends the phenomena of nature to his will, the more he discovers and the more he will continue to discover.
>
> Because of this he will increasingly realise the infinity of the Infinite.

# HISTORICAL APPENDIX

36 Senator Marconi, every inch the public figure, with his wife during the re-opening of the Italian Academy at Rome in 1931.

# CHRONOLOGY

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1874 | Guglielmo Marconi born in Bologna. A. G. Bell working on telephone system. | Italy (unified 1871) pursues stringent economic and constructive foreign policies. |
| 1886 | Marconi attends Cavallero Institute for tuition in physics and chemistry. | Rand Goldrush (South Africa). Seurat: *La Grande-Jatte.* |
| 1887 | Marconi studies at Leghorn Technical Institute. International Semaphore Code comes into general use. Heinrich Hertz detects and produces wireless waves. | Italians advance into Ethiopia to secure position on Red Sea (Suez Canal opened 1869). First and Second Mediterranean Agreements between Britain and Italy. |
| 1889 | Marconi constructs simple radio oscillator. | Italian protectorate established over Ethiopia. Pavlov demonstrates conditioned reflexes. Publication of *Fabian Essays.* |
| 1890-1893 | Marconi studies electrophysics at Leghorn. Independently of each other, Branly and Lodge invent coheror-detector. Death of Heinrich Hertz (1894). | Foundation of Daimler Motor Company. Foundation of Independent Labour Party in Britain (1893). |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1895 | Marconi succeeds in transmitting Morse messages over a distance of two miles. | Ethiopian War: successive defeats for Italy. Roentgen announces discovery of X-rays. |
| 1896 | Marconi and mother travel to England. The Post Office gives him financial backing and encouragement. | Ethiopian War: Italians defeated at Adua; Ethiopia declared independent. Britain's reconquest of Sudan under Kitchener. Becquerel discovers radioactivity. Death of Alfred Nobel. |
| 1897 | Marconi granted British patent for his invention; he registers first private company. Transmitter constructed on Isle of Wight. Popov (Russia) achieves transmission over three miles. | War between Greece and Turkey. Rudolf Diesel perfects diesel engine. Gaugin: *D'où venons-nous?* Gide: *Les Nourritures terrestres.* |
| 1898 | Transmitter constructed at Bournemouth, then moved to Poole; many other stations follow. Marconi reports Kingstown regatta. | Franco-Italian commercial treaty. Battle of Omdurman and taking of Khartoum re-establish British influence in Sudan. Marie Curie discovers radium. |
| 1899 | Life-saving use of radio demonstrated in *Elba* and *Goodwin Sands* disasters. Messages transmitted across Channel. Marconi reports America Cup Race. Demonstrations to United States Navy and Army. | First Hague Peace Conference provides for permanent international court of arbitration. Outbreak of Boer War. Henry Ford founds Ford Motoring Company. Sibelius: *Finlandia.* |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1900 | Formation of Marconi International Marine Communications Co. Preparations for transatlantic wireless link. Station constructed at Poldhu. | Franco-Italian rapprochement. Boer War: relief of Mafeking. Freud: *Interpretation of Dreams*. Maiden flight of Zeppelin dirigible. Puccini: *Tosca*. |
| 1901 | Successful radio communication across Atlantic. Marconi perfects selective tuning system (7777 Patent). | Death of Queen Victoria; accession of Edward VII. Italian radicals organise large-scale strikes. W. Roentgen wins Nobel Prize for Physics for discovery of X-rays. |
| 1902 | Development of magnetic detector. Marconi equips his first floating laboratory, the *Carlo Alberto*. Heaviside and Kennelly independently explain reflection of radio waves by ionosphere. | Treaty of Vereeniging ends Boer War. Balfour's Education Act provides non-denominational State schools. Debussy: *Pelléas et Mélisande*. Gide: *L'Immoraliste*. |
| 1903 | Marconi is made a Roman citizen. Further transatlantic experiments. Dunwoody and Pickard invent crystal detector. | Orville Wright makes first controlled aeroplane flight in history. Becquerel, Pierre and Marie Curie win Nobel Prize for Physics for discovery of radioactivity. |
| 1904 | Death of Marconi's father. Marconi meets Beatrice O'Brien, his future wife. Financial difficulties of Marconi Co. J. A. Fleming develops thermionic "diode" detector. | General strike in Italy. Chekhov: *The Cherry Orchard*. Monet: *Vues de Londres*. Ivan Pavlov wins Nobel Prize for Medicine for his study of the digestive system. |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1905 | Beatrice and Marconi marry in London. Marconi patents horizontal direction aerial. | Einstein formulates Quantum Theory. Freud publishes theories on infantile sexuality. Henryk Sienkiewicz wins Nobel Prize for Literature. |
| 1906 | Birth of Lucia (dies within weeks). Lee De Forest develops "triode" detector. Fessenden is first to transmit music using modulator. | Launching of British *Dreadnought*, the world's first big-gun battleship. Einthoven develops electro-cardiography. Theodore Roosevelt wins Nobel Peace Prize. |
| 1907 | Marconi invents multiple tuner. | First Cubist Exhibition. Rudyard Kipling wins Nobel Prize for Literature. |
| 1908 | Birth of Degna. Beginning of unlimited wireless telegraphy service. | 150,000 die in Calabria (Italy) earthquake. Ernest Rutherford wins Nobel Prize for Chemistry for investigations into radioacte substances. |
| 1909 | Collision disaster of *Republic* and *Florida:* 1,700 saved due to use of radio. Marconi awarded Nobel Prize for Physics, jointly with K. F. Braun. | Old Age Pension Law enforced. Lloyd George's "People's Budget." Blériot makes first Channel crossing by aeroplane. |
| 1910 | Birth of Giulio in Bologna. De Forest uses "triode" to broadcast voice of Caruso. | Stravinsky: *The Firebird.* Kandinsky: *The Art of Spiritual Harmony.* Modigliani: *The Cellist.* |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1912 | *Titanic* disaster: 703 saved by use of radio. Marconi is knighted. His rift with Beatrice patched up; they visit Italy. Marconi loses one eye in car crash. | Italy occupies Tripoli, Rhodes and Dodecanese. Tripolitan War ended by Treaty of Lausanne. Waves of strikes in Britain. Scott reaches South Pole. Shaw: *Pygmalion.* |
| 1913 | *Volturno* disaster: 650 saved by use of radio. | Rise of Italian socialist movement. Tagore wins Nobel Prize for Literature. |
| 1914 | Marconi begins shortwave experiments. He is made a Senatore of Italy. H. J. Round sets up interception stations for enemy transmissions. Adcock develops direction-finding aerial. | General strikes and rioting in Italy; start of Mussolini's political career. Outbreak of World War I: Italy proclaims neutrality. Birth of Tennessee Williams, playwright. |
| 1915 | Marconi appointed officer in charge of wireless communications for Italian army. He continues short wave research, and develops shortwave apparatus for detection of enemy transmitters. | Italy mobilises and enters war on Allied side: battles of the Isonzo. Einstein: *General Theory of Relativity.* Dadaism develops in Zurich. |
| 1916 | Birth of Gioia. Marconi collaborates with J. S. Franklin on shortwave systems. | End of Mesopotamian Campaign. Britain is first to use tanks in field warfare. Battles of Verdun, Somme, Ypres and Jutland. U.S.A. attempts to act as mediator. |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1917 | | U.S.A. declares war on Germany. Collapse of Italy. Max Planck wins Nobel Prize for Physics for hypothesis that radiation is emitted in "quanta." |
| 1918 | Marconi settles in Rome. | Great March offensive. Allied supremacy in the air. Hostilities cease on Western Front. Austria, Hungary and Czechoslovakia become republics. Collapse of Bulgaria and Turkey. |
| 1919 | Marconi attends Versailles Peace Conference. | Peace Treaty of Versailles: resolution adopted for creation of League of Nations. Italy: Communism spreads; rise of Mussolini and Fascists. |
| 1920 | Marconi buys *Elettra* and refits her as a floating radio laboratory. | Official birth of League of Nations. |
| 1922 | In his paper to the American Institute of Electrical Engineers Marconi foresees use of radar. | Series of international conferences to settle aftermath of war. Mussolini is dictator of Italy. Niels Bohr wins Nobel Prize for Physics for his atomic theory. Fridtjöf Nansen wins Nobel Peace Prize. |
| 1923 | Beatrice gains divorce from Marconi and marries the Marchese Marignoli. Further series of shortwave experiments from *Elettra*. De Forest demonstrates first sound-motion picture. | Germany, on verge of financial collapse, is aided by America under the Dawes Plan. W. B. Yeats wins Nobel Prize for Literature. |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1925 | Marconi meets Cristina Bezzi-Scali. Franklin develops flat-type aerial for high concentration of radio beam. Marconi's highly successful trans-world shortwave transmission. | League of Nations plans disarmament commission. Italy: Fascists repress Liberals and Communists. G. B. Shaw wins Nobel Prize for Literature. J. Chamberlain and C. G. Dawes win Nobel Peace Prize. |
| 1927 | Annullment of first marriage enables Marconi to marry Cristina Bezzi-Scali; honeymoon trip to America. Marconi's first attack of angina. | End of Allied military control in Germany. Lindbergh makes first Atlantic solo flight. Italy: universal suffrage abolished. |
| 1928 | J. L. Baird transmits television across Atlantic. | League of Nations' efforts to outlaw war result in Kellogg-Briand Pact. |
| 1929 | Government-owned undersea cable company merges with Marconi Co. to form Cable and Wireless Organisation. Hereditary title of Marchese bestowed on Marconi by King of Italy. | Bank for International Settlements established in Basle. Thomas Mann wins Nobel Prize for Literature. Epstein: completion of carvings in London Transport House. Shaw: *The Apple Cart*. |
| 1930 | Marconi resumes experimental work. Several broadcasts made from *Elettra*. Birth of Maria Elettra Elena Anna. | Italo-Austrian treaty of friendship. Italy builds up her defences. Cocteau: *Les Enfants terribles*. |

| | MARCONI AND RADIO | POLITICS, ARTS AND SCIENTIFIC PROGRESS |
|---|---|---|
| 1931 | Marconi equips Vatican with shortwave transmitter. Marconi's famous world-wide broadcast on 30th anniversary of transatlantic link. | Start of unofficial hostilities between Japan and China. Economic depression in Italy. |
| 1934 | Marconi works on microwave beacons for direction-finding and navigation. *Elettra* is first ship to berth by radar. | Hitler visits Mussolini. Cocteau: *La Machine infernale*. Luigi Pirandello wins Nobel Prize for Literature. |
| 1936 | Marconi's disillusionment with Mussolini regime. | Germany re-occupies Rhineland, thereby violating Treaty of Versailles. Outbreak of Spanish Civil War. German-Italian pact divides Europe. O'Neill wins Nobel Prize for Literature. |
| 1937 | Marconi dies on July 20th after three heart attacks. | Lord Halifax visits Hitler to discover German objectives. |

# THE 1909 NOBEL PRIZE FOR PHYSICS, MARCONI AND BRAUN

Presentation Speech by the former Rector General of National Antiquities H. Hildebrand, President of the Royal Swedish Academy of Sciences.

Your Majesty, Your Royal Highnesses, Ladies and Gentlemen:

Research in physics has provided us with surprises. Discoveries which at first seemed to have but theoretical interest have often led to inventions of the greatest importance to the advancement of mankind. And if this holds good for physics in general, it is even more true in the case of research in the field of electricity.

The discoveries and inventions for which the Royal Academy of Sciences has decided to award this year's Nobel Prize for Physics, also have their origin in purely theoretical work and study. Important and epoch-making, however, as these were in their particular fields, no one could have guessed at the start they would lead to the practical applications witnessed later.

While we are, this evening, conferring Nobel's Prize upon two of the men who have contributed most to the development of wireless telegraphy, we must first register our admiration for those great research workers, now dead, who through their brilliant and gifted work in the fields of mathematical and experimental physics, opened up the path to great practical applications. It was Faraday with his unique penetrating power of mind, who first suspected a close connection between the phenomena of light and electricity, and it was Maxwell who transformed his bold concepts and thoughts into mathematical language, and finally, it was Hertz who through his classical experiments showed that the new ideas as to the nature of electricity and light had a real basis in fact. To be sure, it was already well known before Hertz's time, that a capacitor charged with electricity can under certain circumstances discharge itself oscillatorily, that is to say, by electric currents passing to and fro. Hertz, however, was the first to demonstrate that the effects of these currents propagate themselves in space with the velocity of light, thereby producing a wave motion having all the distinguishing characteristics of light. This discovery—perhaps the greatest in the field of physics throughout the last half-century—was made in 1888. It forms the foundation, not only for modern science of electricity, but also for wireless telegraphy.

But it was still a great step from laboratory trials in miniature where the electrical waves could be traced over but a small number of metres, to the transmission of signals over great distances. A man was needed who was able to grasp the potentialities of the enterprise and who could overcome all the various difficulties which stood in the way of the practical realization of the idea. The carrying out of this great task was reserved for Guglielmo Marconi. Even when taking into account previous attempts at this work and the fact that the conditions and prerequisites for the feasibility of this enterprise were already given, the honour of the first trials is nevertheless due, by and large, to Marconi, and we must freely acknowledge that the first success was gained as a result of his ability to shape the whole thing into a practical, usable system, added to his inflexible energy with which he pursued his self-appointed aim

Marconi's first experiment to transmit a signal by means of Hertzian waves was carried out in 1895. During the 14 years which have elapsed since then, wireless telegraphy has progressed without pause until it has attained the great importance it possesses today. In 1897 it was still only possible to effect a wireless communication over a distance of 14-20 km. Today, electrical waves are despatched between the Old and the New World, all the larger ocean-going steamers have their own wireless telegraphy equipment on board, and every Navy of significance uses a system of wireless telegraphy. The development of a great invention seldom occurs through one individual man, and many forces have contributed to the remarkable results now achieved. Marconi's original system had its weak points. The electrical oscillations sent out from the transmitting station were relatively weak and consisted of wave-series following each other, of which the amplitude rapidly fell—so-called "damped oscillations." A result of this was that the waves had a very weak effect at the receiving station, with the further result that waves from various other transmitting stations readily interfered, thus creating confusion at the receiving station. It is due above all to the inspired work of Professor Ferdinand Braun that this unsatisfactory state of affairs was overcome. Braun made a modification in the layout of the circuit for the despatch of electrical waves so that it was possible to produce intense waves with very little damping. It was only through this that the so-called "long-distance telegraphy" became possible, where the oscillations from the transmitting station, as a result of resonance, could exert the maximum possible effect upon the receiving station. The further advantage was obtained that in the main only waves of the frequency used by the transmitting station were effective at the receiving station. It is only through the introduction of these improvements that the magnificent results in the use of wireless telegraphy have been attained in recent times.

Research workers and engineers toil unceasingly on the development of wireless telegraphy. Where this development can lead, we know not. However, with the results already achieved, telegraphy over wires has been extended by this invention in the most fortunate way. Independent of fixed conductor routes and independent of space, we can produce connections between far-distant places, over far-reaching waters and deserts. This is the magnificent practical invention which has flowered upon one of the most brilliant scientific discoveries of our time!

37 Michael Faraday, the brilliant, self-taught British scientist who laid the foundations for the electrical and elecromagnetic developments of our time.

## MICHAEL FARADAY
(1791-1868)

Faraday was one of the greatest of British scientists, but he was mathematically illiterate. His lack of education, however, was more than made up for by his extraordinary ability to visualize the most complex of scientific problems. For instance his intuitive picturing of magnetic fields—at the time an entirely new concept—was later formulated in mathematical terms by Maxwell.

One of ten children, Faraday was the son of a blacksmith. For him a formal education was out of the question. When he was still a boy the family moved from Newington, in Surrey, to London where he was apprenticed to a bookbinder. Young Faraday, hungry for knowledge, soon found himself surreptitiously reading the books that he was binding. This self-education he supplemented by attending public lectures given by scientists at the Royal Institution. Faraday was particularly influenced by the talks of Sir Humphry Davy, inventor of the miners' safety lamp. Such was Faraday's intelligence and determination that in 1813, at the age of twenty-three, he became Humphry Davy's assistant. A bit too keen, Faraday quickly pointed out possible improvements to the miners' lamp. This didn't go down too well with Davy who resented it, and for several years Faraday was held back by the jealousy of the older man.

Faraday's rise was, however, fairly spectacular. By 1825 he was the head of Davy's laboratory at the Royal Institution. At the age of thirty-three he was elected to the Royal Society, in 1833 he was appointed professor of chemistry at the Royal Institution. By this time he had already devised methods for liquefying gases under pressure. He could produce below zero (Fahrenheit) temperatures and opened the way for the growth of cryogenics—the science of very low temperatures.

Active in many fields, Faraday's greatest achievements were in electrochemistry—the liberation of metals from a solution by passing an electric current through the liquid. Davy claimed that Faraday had merely found a name to describe something that he had already discovered, but Faraday's achievement was more than one of mere terminology. By working out the specific amount of electricity needed to release an element, Faraday put electrolysis into quantitative terms, bringing electrochemistry into the realm of science rather than cookery. In honour of Faraday the amount of electricity required to liberate "an equivalent weight" of an element is called a Farad, as is the basic unit of capacitance.

Marconi's most significant work was in the area of electromagnetism and it is here, too, that Faraday made his most significant contribution to science. His discovery of electromagnetic induction led to the development of the dynamo and the electric motor. In 1821, adapting an experiment made by Oersted, Faraday carried out an extensive series of experiments which demonstrated that both electrical and magnetic energy could be converted into mechanical movement. A similar series of experiments was being conducted simultaneously by Joseph Henry in the U.S.A.

Faraday was more interested in the reverse process of producing an electric current by methods involving magnetism and mechanical motion. He did this by putting a magnet into a coil of wire. While the magnet was moving a galvanometer attached to the coil registered an electric current. When coil and magnet were motionless no current showed. In other words, an electric current was momentarily created by the movement of the magnet. This process is known as *induction*. It was discovered independently by Joseph Henry, whose method was a little more spectacular. He produced sparks when he disconnected a long wire coiled around an iron core.

The first steps towards a theoretical understanding of induction were made by Faraday when he explained the process in terms of "lines of force." When the wire cut through the magnetic lines of force around the magnet an electric current was induced. This was the very early basis for the *field* theory of action, which has since swept through the whole of physics, and presents one of the most powerful mathematical as well as conceptual tools for scientists in their explanation of physical events.

These early steps were really no more than a curtain-raiser for the more epoch-making events that followed. In 1831 Faraday was able to induce a *steady* flow of electricity from a magnet by rotating a copper disc between the *poles* of the magnet. Here was the beginning of today's giant dynamos and generators, but having given the idea to the world Faraday went no further. He knew that to transfer scientific achievements from the laboratory into something that could be useful would take many years.

In later years Faraday turned his attention to the interaction of light and magnetism. In 1845 he discovered that when polarized light passes through a piece of heavy glass, placed between the poles of a magnet, the plane of polarization rotated (the Faraday effect). During this time Faraday was asked by the government to supervise the production of poison gas for use in the Crimean War. He refused! His high ideals and sense of responsibility were reinforced by his membership of a strict Protestant sect. He disdained wordly honours, refused a knighthood, and requested that he be buried beneath "a gravestone of the most ordinary kind." In fact the only honour that he seemed to value was his membership of the Royal Society.

Faraday's last years were accompanied by failing memory and it is possible that he died, like his fellow chemists Davy and Scheele, of chronic low-grade poisoning.

# JOSEPH HENRY
(1797-1878)

Joseph Henry's career and achievements were remarkably similar to Faraday's, and it is surprising that he is so underrated today. He was a physicist rather than an inventor, but this does not explain why credit that should have been his went to men like Faraday and Morse. It may just be that geography denied him true recognition, since during this period the centres of scientific achievement were in Europe. The very revolution in communication that men like Henry and Faraday were forging was soon to close the huge gap of the Atlantic Ocean.

In many ways Henry was a model scientist; he was an excellent administrator, generous, persevering, forward-looking and dedicated to furthering the international exchange of scientific ideas. As a boy Henry was apprenticed to a watchmaker. At the age of sixteen the magic of books struck him; the accidental discovery of a shelf of books in a church awakened in him the ambition and curiosity to return to school. He learned quickly, paying his way by tutoring others in his spare time. His natural tendency was towards medicine rather than physics, but he changed when, after graduating, he was offered a job with a surveyor and became interested in engineering. It may have been this that caused him to think in bigger terms than people like Faraday; Henry's experiments seem to have been quite spectacular in their time.

By sheer will-power and perseverance Henry obtained a post as mathematics teacher at the Albany

Academy, New York, just thirteen years after he decided to return to school.

There had been few spectacular electrical experiments in America since those of Benjamin Franklin nearly a century earlier. But by 1831 Henry had so improved on the weak electromagnet that, in a demonstration at Yale University, his apparatus lifted over a ton of metal. Henry had found a way of reinforcing the magnet by using as many insulated conducting wires as could be wound round an iron core.

The sheer magnitude of this feat was indeed an achievement, but more useful was the delicate experiment that opened the way for the telegraph, an invention for which Morse later claimed priority. Henry used a small spring-controlled iron bar situated a short distance from the end of a length of wire terminating in an electromagnet. When current flowed through the mile-long wire, the bar made contact with the magnet, and when the flow was broken it sprang away. The opening and closing of the circuit could make a meaningful pattern of signals which could be received at the magnet end. This method had the disadvantage that the signal got weaker over long stretches of wire. Not beaten, Henry invented a relay system in 1835. After initial scepticism, Henry eventually did all he could to help Morse in his commercialisation of the telegraph after 1844.

A few years earlier Henry had been just beaten by Faraday in publishing news of his discovery of induction, a phenomenon that Henry had discovered and noted some months earlier; but a heavy teaching programme had prevented him from writing it up. When he did publish his results Henry was able to point out something that Faraday had missed: the principle of *self-induction.* As well as inducing a current in a secondary coil, the primary coil induced a current in itself over and above the original current. For this Henry was given credit. He is also recognised as having built the first step-up and step-down transformers.

The electric motor has been one of the most revolutionising forces in life since the middle of the nineteenth century. In a paper published in 1831 Henry describes a simple motor, reversing the generator principle in which mechanical force produced electricity. He was one of the first to realise that electricity could also generate mechanical force.

Like Faraday a man with wide interests, Henry's work in meteorology led to today's United States Weather Bureau. This is a descendant of Henry's system of obtaining weather reports by telegraph. During the Civil War Henry was put in charge of scientific mobilization, playing a role in the U.S.A. similar to that of Vannevar Bush in the Second World War.

Henry died in Washington in 1878 and was accorded a magnificent funeral. In 1893 he at last received credit for his discovery of inductance when the International Electric Congress, meeting in Chicago, decided to name the unit of inductance the henry. As a final accolade he was elected to the Hall of Fame for Great Americans in 1915.

## SAMUEL FINLEY BREESE MORSE
(1791-1872)

Morse was not a scientist. His contribution to science was more his vision of the *possibilities* of long-distance communication, and his ability to get people to support him in his attempts to build a communications system. Born in Charlestown, Massachusetts, the eldest son of a clergyman, Morse was originally an artist. He was educated at Yale where he concentrated on painting miniature portraits. Morse travelled to Europe to learn about the various schools of painting, studying English painting in England, from 1811 to 1815, with Washington Allston. While in the country he was aroused by the experiments in electromagnetism that were then taking place. He returned home in 1832, and on the journey conceived the idea of a single-circuit telegraph system. But Morse was known as an artist rather than a scientist, so very little attention was paid to his scheme.

It is to Morse's credit that he ignored his rejection by those who "knew better." By 1835 he had made his first working telegraph, using an old picture frame and the silk-covered wire normally employed by high-class milliners for making hats for society ladies. Morse's system of communication used the code of dots and dashes that still carries his name, a code he patented in 1840. Using this system Morse was able to communicate over a distance of ten miles; but little interest was aroused. After early collaboration with Leonard Gale, the Vail family—owners of a Morristown iron works—and Congressman F. O. J. Smith of

Maine, Morse carried on alone for another six years.

Money was finally granted to Morse in 1843 by Congress, which approved the building of a line between Washington and Baltimore at a cost of $ 30,000. But finance wasn't the only thing that help up Morse. The public were not exactly rapturous about the new invention. Landowners refused permission for wires to go over their land, farmers destroyed a line because it was "taking the electricity from the air and spoiling the weather."

The telegraph was the subject of long court battles over patent rights. But Morse won his fight with earlier partners and rival inventions; in 1854 his right to the patent was recognised. Fame also came from Europe, where many governments rewarded Morse for his invention. Originally conceived as a means for communicating information about transactions on the stock exchange, the telegraph in time caused the world to shrink. After several abortive attempts, a cross channel link was set up in 1858, only to break after three weeks' operation. Eventually, by the turn of the century, a worldwide communications system had been established. This remained unchallenged until Marconi started his work on radio.

Morse was eventually appointed Professor of Natural History at Yale. Much acclaimed and honoured as a scientist, he died in New York in 1872. The last years of his life he spent as a philanthropist.

## SIR CHARLES WHEATSTONE
(1820-1875)

As with most discoveries and inventions, the telegraph was not the result of just one person's work. While Morse and Henry were at work in the U.S.A. Wheatstone was experimenting in England. In 1868 he was knighted for his pioneering work on the telegraph in England. His system, developed in collaboration with W. F. Cooke and with help from Joseph Henry, was patented in 1837. The first English telegraph line was laid alongside the London to Camden Town railway track. The second ran a full twenty miles from London to Slough.

Another scientist with far-ranging interests, Wheatstone also worked on acoustics—producing the first concertina, and on optics—inventing the stereoscope (a device for duplicating mechanically the visual or binocular effect of depth perception). Wheatstone's knighthood was also awarded in recognition for his improvements to electrical generating systems. In 1841 he developed a way of making the flow of current smoother than it had been before.

The name of Wheatstone is today remembered in the *Wheatstone Bridge*, which allows for the very accurate measurement of the resistance of a circuit. Really this device was not invented by Wheatstone, but he was the first to bring the kaleidophone, as it was known, into prominence.

Another member of the family also produced an important contribution to electromagnetism. Wheatstone encouraged his nephew, Oliver Heaviside, in his ambitious programme of self-education. It was Heaviside who, in his *Electromagnetic Theory* (1902), suggested that radio waves might be made to travel around the earth by bouncing them off an ionized layer in the upper atmosphere. This was put forward just one year after Marconi had successfully transmitted radio waves across the Atlantic. Proof that this layer existed had to wait until the work of Appleton, who showed experimentally, in 1925, that this layer actually did exist.

38 James Clerk Maxwell, the Scottish scientist, who in the mid-nineteenth century laid down the mathematical and theoretical basis for the transmission of radio waves. Hertz actually detected electromagnetic waves in 1887. Then came Marconi, who was responsible for the practical realization of radio.

# JAMES CLERK MAXWELL
(1831-1879)

A half century before people like Marconi were carrying out experiments in the transmission of radio waves, Maxwell was laying the mathematical and theoretical basis for this work. After graduating second in his class from Cambridge, Maxwell returned to his native Scotland (he was born in Edinburgh) to become a professor at Aberdeen. From here he went to London where he became Professor of Physics at King's College. These years, from 1860 to 1865, were highly productive, and it was during them that Maxwell met Faraday. Maxwell then returned to his Scottish estate, where he worked on his great *Treatise on Electricity and Magnetism.* In 1871 he accepted the Chair of Physics at Cambridge, where he remained until his death.

It was the period with Faraday that led to Maxwell's great achievement of describing electromagnetism in mathematical terms. Faraday played a big part in this with his instinctive visualization of the electric *field.* But whereas Faraday was thinking visually in terms of lines and tubes of force, Maxwell produced a mathematical formulation of the same concepts. Like Oersted, both Faraday and Maxwell were interested in an all-embracing description of physical events. The field theory provided such a possibility, and Maxwell's equations actually described such a system. Light, electricity and magnetism were all neatly linked together.

A direct prediction that came from Maxwell's equations was the existence of electromagnetic waves, of which radio waves are just one example. Moreover Maxwell was able to predict the properties of these waves from his equations. For example, he calculated the speed at which they would travel; this he found to be 186,000 miles per second or the speed of light. These waves were first actually produced by Hertz in 1886, but they were not used for communication until the turn of the century, when Marconi succeeded in sending radio waves across the Atlantic.

# KARL FERDINAND BRAUN

(1850-1918)

Marconi and Braun had not met before they came together in Stockholm in 1909 to receive the Nobel Prize for Physics, which they had been awarded jointly for their services to radio. In 1901 Marconi had transmitted radio waves across the Atlantic. Professor Braun had improved Marconi's original apparatus and had introduced the coupled transmitter. But, whereas Marconi passionately believed in the future of radio communications, Professor Braun was a little more reticent in his predictions. In a lecture in 1900 he expressed doubts that radio would ever replace the telegraph. No doubt he changed his mind as his, and others', work resulted in better systems.

As well as his work on radio Professor Braun had developed an original type of cathode ray tube, the forerunner of today's television tube. His work was aimed at making rapid electrical impulses visible. The cathode ray tube consisted of a vacuum tube filled with fluorescent gas. A heated cathode emits a beam of fast electrons which strike the screen at the other end of the tube. A picture appears on the screen and can be seen from the outside. If the beam is deflected by a magnet the cathode ray "draws" a line on the screen. Changes in the brightness of this line can be related to variations in the strength of the electric current driving the beam. His tube, constructed in 1895, while Braun was Professor of Physics at Strasbourg, could be used to show up the finest variations in electric current.

Twenty-one years before this Braun had noted that certain crystals transmitted electricity better in one direction than they did in the opposite direction, a discovery that later proved vital to Fleming's development of the rectifier in 1904. These crystals were also used in the earliest radios, "crystal sets" as they were known. Replaced for a while by valves, similar devices were reintroduced into the first transistor radios.

Clearly Braun's developments were mostly years ahead of their time. Notoriously in the wrong place at the wrong time, Braun happened to be in New York during the First World War, in connection with patent litigation. When the United States declared war on Germany in 1917, Braun was interned. In 1918 he died.

## SIR OLIVER LODGE
(1851-1940)

Lodge was carrying out experiments into electromagnetism at the same time as Hertz and Marconi. Both Branly in France and Popov in Russia had found that when metal particles were pressed together they offered a high resistance to a direct electric current. Lodge thought that a vial of filings, acting as a coherer, could be used to detect Hertzian waves. His pioneer work on radio communications earned him a knighthood in 1902.

To some a genuine scientist, Lodge was considered by others an eccentric, since he dabbled in the field of psychic phenomena. At least his mind was open to all ideas. The death of a son in the First World War strengthened his belief in a life after death. Lodge was a prolific writer who set himself the task of reconciling science and religion, as is shown by the titles of some of his books: *The Substance of Faith* (1907), *The Survival of Man* (1909), *Raymond, or Life and Death* (containing an account of his supposed communication with his dead son) (1916), *Why I Believe in Personal Immortality* (1928), and *Beyond Physics* (1930). At the same time as he was writing these outrageously unscientific treatises he was also writing books discussing the most up-to-date science: *Modern Views of Electricity* (1889), *Life and Matter* (1905), *Atoms and Rays* (1924), *Relativity* (1925) and *Advancing Science* (1931).

As well as working on electromagnetism, Lodge tried, in 1893, to determine whether matter exerted a drag on the mythical "ether." His experiments were negative, as were those of Michelson and Morley in 1887. Lodge was also an early convert to the atomic theories of Rutherford and Soddy. In 1894 Lodge suggested that the sun might be emitting radio waves, which was shown to be so in 1942.

*Past Years*, Lodge's autobiography, finished in 1931, showed that since 1910 he had concentrated more and more upon psychic research. But his preoccupation with the past and the future didn't suggest the patenting of any of his inventions. They were free for the use of all, including Marconi.

## REGINALD AUBREY FESSENDEN
(1866-1932)

Almost unheard-of in comparison with Edison and De Forest, Fessenden was second only to Edison in the number of patents that resulted from his work on radio and in other fields. When he died he had over five hundred patents to his name. During the late 1880's he worked as chief chemist for Edison, then for Edison's great rival, Westinghouse, from 1890 to 1892. Fessenden's most valuable contribution to radio telephony, as distinct from radio telegraphy, was his development of the modulator in 1906. He had already improved on the coherer of Branly and Lodge with his electrolytic detector. This consisted of a fine platinum wire resting on the surface of an acid forming a bubble, which stopped the flow when a direct current was passed through the wire. An alternating current, as produced by a wireless signal, burst the bubble and allowed continuous transmission.

Fessenden's modulator was a logical extension of his work on electrolytic detectors. Radio signals had previously been transmitted in a series of pulses, imitating the dots and dashes of the Morse code. It occurred to Fessenden that if a continuous wave was transmitted, then variations in the size of the wave could be used to transmit speech and music. For this he planned to use a high-frequency wave as a carrier wave, inaudible to the human ear but capable of travelling great distances. On to these would be superimposed waves of a similar frequency, generated inside the receiver, the difference between the two frequencies being then audible to the human ear. An ingenious scheme, but one which remained impracticable until De Forest's work on the heterodyne principle. Fessenden's first continuous sound signal was sent out from the coast of Massachusetts in 1906. Although far from perfect, the strains of music were audible and recognisable.

## LEE DE FOREST
(1873-1961)

A major step forward in the transmission of radio signals was De Forest's invention of the triode valve. Previously the thermionic valve had been no more than a hot cathode emitting electrons and an anode receiving them. In 1906 De Forest introduced a third electrode; the current flowing through the valve could then be controlled by very small variations in the voltage applied to the grid, the third electrode.

De Forest obtained his Ph. D in 1899 after graduating from Yale in 1896. Between these two dates he served in the Spanish-American war. After this he started to devise methods of speeding transmission of radio signals. He had been interested in this ever since his schooldays. De Forest was an indefatigable and brilliant inventor, but, like many inventors he lacked business sense, and thus did not make a great deal of money out of his inventions. Speeded transmission was first put to the test in reporting the Russo-Japanese war—the first instance of modern war correspondence.

The full impact of the triode valve, or "audion" as De Forest called it, is best appreciated by realising that variations on the basic principle remained unchallenged in radio transmission until the invention of the transistor by Shockley in 1948. The introduction of the extra grid led to a whole variety of electronic devices. In 1910 De Forest adapted Fessenden's modulator to broadcast the singing voice of Enrico Caruso. By 1916 he was broadcasting the news from his own radio station.

Until Shockley invented the transistor in 1948, the De Forest triode, or audion, remained in supreme command. The triode represented a billion dollar industry in America, but those billions never flowed into the inventor's pocket. In fact, De Forest sold his audion to the American Telephone and Telegraph Company for $ 390,000, a sum which hardly reflected the immense potential of the invention, but which did compensate for the hand-to-mouth existence of earlier years. On one occasion De Forest was arrested for fraudulent use of the postal services; he was trying to raise funds to finance his triode invention. Patent litigation dogged many of his inventions.

In 1923 his brilliance as an inventor was underlined by his demonstration of the first sound motion-picture. Since 1920 he had been experimenting with a "glow-lamp"—a device for converting sound-waves into corresponding irregularities in the brightness of a lamp filament. The filament brightness could then be photographed simultaneously with a motion picture, and the varying brightness of the "soundtrack" finally reconverted into sound. By 1928 the talkies were a commercial proposition, and the world of the silent movie slipped into the archives of cinema history. De Forest died in Hollywood, California, in 1961.

39 Early radio broadcasting over the BBC. Until the 1920's radio broadcasting was envisaged in practical terms, such as radio telegrams and communications at sea. Then, unexpectedly and suddenly, radio was transformed into a vigorous branch of the entertainment industry.

## EDWIN HOWARD ARMSTRONG
(1890-1954)

Armstrong first put his Columbia degree in electrical engineering to use during 1917-1919, when he was an officer in the United States Army Signal Corps. His interest in the subject had begun in his early teens. He delved into accounts of Marconi's experiments and emulated him by building his own radio transmitter and broadcasting from it. By the age of twenty-four he had developed a sensitive feedback receiver—introducing a circuit which offered greater reliability for receiving signals.

Armstrong's next significant achievement concerned the detection of enemy aircraft. Existing systems had relied on the picking up of aircraft sounds, but Armstrong believed that it would be more efficient to detect the radio waves coming from their ignition systems, even though this posed the difficulty of converting very high frequency waves to a lower frequency, and then amplifying them. Unfortunately Armstrong's "superheterodyne" detector, as he called it, was developed too late for use in World War I, but was in general use for radar during World War II. In the interim, all radio sets were equipped with heterodyning, which meant that a listener could tune in to any frequency at the twist of a dial. The superregenerative circuit, which Armstrong developed in 1920, was only an augur of his next brilliant contribution to radio technology, *FM*, or frequency modulation, which provided the solution to the problem of "static" radio disturbances due to atmospheric conditions or to faulty apparatus. FM is superior to the more common audio modulation, which does not guard against interference because the amplitude of the carrier wave can be randomly modulated by it. By modulating the frequency, as in FM, static is practically eliminated.

Armstrong was continually engaged in litigation, which seems to have been a perennial feature of early radio. Armstrong, however, had an almost paranoid conviction that he was the victim of a conspiracy, and in 1954 committed suicide by jumping from his New York apartment window.

## GLOSSARY OF TECHNICAL TERMS

### Pertaining to the work of Marconi

*Aerial* or *Antenna* (plural *Antennae*). The point at which radio waves are radiated outwards from a transmitter or picked up by a receiver. Aerials have taken many forms, and they still do. Marconi's first aerial was a thin sheet of metal suspended vertically from a bamboo cross-bar. But soon the commonest aerial was simply a single trailing insulated wire, suspended either vertically or horizontally. The efficiency of such an aerial is greatly increased if two parallel wires are used. This type of aerial is still sometimes seen. More often today aerials are complicated systems of wires, rods, discs, dishes, bowls or other metallic conductors. Nowadays many radio receivers work well with no visible aerial at all. These operate on small internal iron ferrite rod aerials (or loopsticks) built inside the casing of the set and often only a few inches long. Each rod is closely wound with many loops of very fine wire, and such aerials give excellent results on comparatively short ranges. They are highly directional, as anyone who owns a transistor set knows, giving maximum results only when they face the transmitter. Modern radio sets often have a telescopic aerial that folds down inside the casing when not in use. This again is but a refinement of the wire type. In many radio systems (ships, aircraft, police cars, etc.) the same aerial is used for both transmitting and receiving.

*Alternating Current* (A. C.). A flow of electricity which is continually changing its strength and direction in a regular wavelike way, with a smooth increase from zero to maximum, decreasing through zero to the same maximum, then back to zero to commence the next cycle. This S-shaped wave-pattern is identical to that of an emitted radio wave, and an alternating current travelling along a wire has its own *frequency*, or number of such cycles per second. In Britain, A. C. is almost universally used for mains electric power, and the frequency is 50 cycles/second. See also *Direct Current.*

*Amplifier.* Any device used to amplify, or increase the power of small signals, usually at the receiving end. Early radio used no amplification at all, but all modern receivers are based on an amplifier circuit, using either valves or transistors to enlarge even the weakest signals until they are strong enough to operate a loudspeaker. The prime requirement of an amplifier is that it must not distort the received signal too much.

*Antenna.* (See *Aerial*).

*Anode.* The positively-charged electrode in a radio valve which accepts the electrons emitted by the cathode.

*Atmospherics.* (See *Static*).

*Audio Frequencies.* The audible frequencies of sound waves, which vary from about 30 cyles/second (the lowest notes) up to 20,000 cycles/second (the highest notes, a high-pitched squeak, often inaudible to older people). A good loudspeaker can convert any electrical signal from 30 c/s to around 15,000 c/s into audible sound waves. In radio, the term *audio* is often used to denote any signal or sound audible to the human ear. See also *Radio Frequencies*.

*Battery.* Any chemical device that produces an electric current. The individual productive sections of a battery are usually called cells. These "small electrochemical factories" still play an important part in radio, as they have always done.

*Beam Transmission.* Radio waves sent out from the transmitting aerial in one chosen direction only.

*Call Sign.* The combination of letters and/or numbers allocated to a particular transmitting station, used as an identifying signal. One of the most famous of all call-signs was 2LO, the first London broadcasting station, operating from Marconi House in 1922. Every transmitter has its own call-sign, including ships, aircraft, mobile services and amateurs.

*Carrier Wave.* Radio wave of a set frequency, used to transmit radio or television signals. The carrier wave is a steady alternating wave which is modulated to carry the required broadcast.

*Cathode.* The negative electrode in a valve which, when heated, provides a flow of electrons to the anode.

*Cathode Ray Tube.* Device in which electrons (cathode rays) are emitted by a heated filament, confined to a narrow beam, accelerated and made to hit a fluorescent screen at the end of the tube, e. g. a radar screen or television screen. Under the electron impact the screen glows visibly. The beam can be deflected horizontally and vertically to produce a picture or moving pattern, as required.

*Coherer.* As invented by Edouard Branly, this was the first efficient detector of radio waves. It consisted of a fine glass tube loosely packed with minute metallic filings which clung together, or cohered, when electromagnetic waves (as from a receiving aerial) passed through them. The filings thus served as a conductor, allowing the alternating impulses to pass through in one direction only, and so be made to operate a bell switch, or a relay, or a Morse inker. The early coherers needed to be tapped by the operator, after each signal impulse was received, so that the filings would loosen again, or "de-cohere," ready to react to the next impulse. A self-cancelling coherer was later devised, but this rather crude piece of wireless apparatus was eventually superseded, first by Marconi's magnetic detector, then by valves, crystals, and transistors.

*Coil.* (See *Induction Coil*).

*Condenser.* Usually nowadays called a capacitor, this device has the property of being able to store an electrical charge. It usually takes the basic form of two electrical conductors separated by insulating material arranged parallel to each other. The "Leyden jar" was the first type of condenser used.

*Conductor.* A substance that permits the free flow of an electric current through it. Many metals are good conductors, which is why metal wires are used in circuits. Good conductors include: silver, gold, copper, brass, platinum, tin, lead, water. Iron and carbon are less good conductors, while certain substances normally refuse to conduct electricity, and so make relatively good insulators. These include rubber, bakelite, wood, ebony, ceramics and various plastics, especially polyvinyl chloride. See also *Semiconductor*.

*Crystal Set*. It was K. F. Braun, who first showed, in 1874, that crystals of galena, copper pyrites and other similar minerals allowed the flow of electricity through them in one direction but resisted flow in the opposite direction. This fact was later exploited in the crystal set, which used a small crystal in a mount with a small wire feeler, or "cat's whisker." The crystal served as the detector, taking the place of the coherer.

Crystal sets remained highly popular for a number of years because of their simplicity, cheapness and lack of need of batteries or any power supply. They were in principle very crude. Rarely did a crystal set produce sufficient volume to work a loudspeaker. Such sets would occasionally be put out of action by heavy bursts of atmospherics, or static. In due course valve sets replaced crystal sets. They provided amplification so that a speaker could be used, but the idea of the crystal re-emerged after World War II in the transistor.

*Cycle*. A single complete oscillation, from zero power back to zero, of any electromagnetic wave. The complete cycle of a radio wave forms the basis of its frequency, expressed as so many cycles/second (c/s). To make this easy in practice, where high frequencies are common, two larger multiple units were introduced, the kilocycle (1000 c/s), and the megacycle (1,000,000 c/s). These were abbreviated to kc/s, and mc/s, but are now giving way to the general use of the term Hertz (Hz) for cycles/second, which gives us Kilohertz and Megahertz. A medium wavelength of 300 metres has a frequency of 1.0 Megahertz.

*Daylight Effect.* Marconi discovered, in the early days of radio, that long-distance signals came through well during the hours of darkness but faded, often to less than half their power, during the daylight hours. The effect is caused by the lower reflective powers of the ionospheric layers, when they are affected by the sun's rays.

*Daylight Wave.* The name given to the very short waves used by Marconi in the 1920s as a sky wave, to give good reception over very long distances by both day and night. The wave was effectively bounced back from the ionosphere and so finally overcame the troublesome daylight effect (see above).

*Detector.* Any device used to separate the audio signal from the carrier wave carried down from the aerial. In chronological order, radio detectors have taken the form of the coherer, magnetic detector, crystal, valve and transistor.

*Diode.* Valve with two electrodes. The first type of valve invented.

*Direct Current* (D. C.). Electric current flowing in a constant direction, often derived from a battery. See also *Alternating Current.*

*Dynamo.* Mechanical device for producing electrical energy from mechanical energy. It makes use of Faraday's discovery of magnetic induction, and usually has a coil rotating in a magnetic field. Continuous rotation of the coil induces a current to flow through its wires. Most electric power supplies today are derived from generators working on the same basic principle.

*Earthing* (or *Grounding*). The earth forms an important part of the aerial system, and it was Marconi who first used this way of completing a radio circuit. (This is not the same as earthing a piece of electrical equipment for safety).

*Electric Charge*. This is really the electrical state of a body, with either an excess or a deficit of electrons. An excess of electrons results in a negative charge, and a deficit in a positive charge. Like electric charges repel; unlike ones attract each other. If a charge is made to move, an electric current results. If a charge is suddenly accelerated or retarded, electromagnetic waves are radiated. It is upon these that all radio depends.

*Electrode*. Conductor or terminal through which an electric current passes, for example the anode and cathode of a valve are electrodes.

*Electromagnetic Waves*. The radiated wave-patterns of the associated electric and magnetic fields from a source. Radio waves are just one form of electromagnetic waves; others include light, infrared rays, ultraviolet rays and X-rays. These operate at different frequencies, but all travel at the same speed—186,000 miles per second.

*Electron*. The basic unit of electricity, a minute negative electric charge which is virtually weightless.

The electron is a fundamental part of the atom, the basic building-brick of the universe. An atom consists of a tiny nucleus carrying a positive electric charge. Around this revolve electrons.

*Ether.* The mythical medium through which light, and all electromagnetic waves, were once thought to be transmitted.

*Feeder.* The transmission line carrying signals from the transmitter to the aerial. Aerials can be fed at each end, in the middle, or at a number of points along their length.

*Frequency.* In radio, the number of complete events of a wave cycle occurring per second. Nowadays the frequency of a transmitting station is quoted rather than the wavelength. In the old spark-transmitters, the frequency of the transmitted signal depended on the number of turns of wire in the spark coil, often around 100,000 cycles/second. Nowadays transmitting frequencies are controlled more exactly by an oscillator.

*Galvanometers.* The general term for an instrument which detects or measures an electric current. It employs a magnet or magnetic coil to move a pointer across a scale. The instrument is named after the Italian scientist, Luigi Galvani (1737-1798), famous for his experiments in making frogs' legs twitch when an electric current was passed through them.

*Grid.* The third electrode in a valve which controls the electron flow, and allows the valve to be used as an amplifier.

"*Ham*". A radio amateur, usually with his own transmitter as well as receiver, operating on certain shortwave bands. The ham movement dates from the earliest days of radio and now includes over 350,000 licensed amateurs, many of whom build their own equipment.

*Hertzian Wave.* The name originally given to deliberately-produced oscillatory electromagnetic radiations (after the German physicist, Heinrich Hertz, who first demonstrated them). They subsequently became known as etheric, Marconi, wireless and, finally, radio waves.

*Induction Coil.* As used by Marconi (the Ruhmkorff coil), this consisted of a primary coil of a very few turns of thick copper wire wound over a bundle of soft iron rods, with a secondary coil of very many turns of very fine wire wound over the top of the primary. When current from a battery is passed through the primary coil and broken intermittently by a spring-operated terminal, a very high voltage alternating current is induced in the secondary coil. He fed this to his spark gap to generate radio waves. An induction coil is a type of transformer.

*Insulator.* Any substance which, by virtue of its very poor conductivity of electricity, is used to prevent the dissipation of electrical energy into space, down to earth (as on an aerial or power pylon) or through contact with other metal parts. Common insulating materials are rubber, p. v. c., glass, porcelain, ceramic materials, bakelite and many other plastics.

*Ion.* An atom that has lost or gained one or more electrons, and so carries a positive or negative electric charge. If the atom has lost an electron and is therefore ready to attract an available electron, it is called a positive ion; if it has gained an extra electron to its normal quota, it is known as a negative ion. See *Ionosphere.*

*Ionosphere.* The layers of ionized gases in the upper atmosphere above the earth which reflect back to the ground radio waves that strike them at an angle. With certain waves, like the daylight short waves, one or more of these layers may bounce them back to earth and then receive more reflected waves back again and again. This enables certain short wave transmitters to encircle the earth with their signals. After dark, because of the changing degree of ionization caused by the sun's rays in daylight, and the lower atmospheric temperature when the sun no longer shines on the layers, they change—in some cases moving away from the earth. This has two important effects. The less heavily ionized layers become less dense and reflect radio waves better than by day. Also, the highest (Appleton) layers involve the transmitted radio waves in a much longer first hop from earth, with the result that they cover the globe more readily. Both of these effects result in much better radio reception after dark, often making it possible to pick up distant stations that cannot be heard by day.

*Leyden Jar.* One of the earliest types of condenser, or battery, for storing an electric charge. First used at the University of Leyden, in Holland, in 1754, and perfected a few years later, it was basically a thick glass bottle or jar coated inside and out with a layer of tin-foil. The outside is earthed and a tall metal ball terminal stands up from the centre of the jar. Each jar is charged from some form of mechanical generator. The device was refined as time went on, so that eventually an array of six, ten or even more such jars would provide a useful voltage source when fully charged and connected.

*Long Wave.* Radio wave of a length from about 1,000 metres upwards.

*Medium Wave.* Radio wave of a length from about 180 metres to 580 metres.

*Microwave.* The very shortest radio wave, below 30 centimetres in length.

*Modulation.* The name given to the process of altering or affecting a transmitted radio wave so that it will carry speech, music, natural sound and television pictures. Normally an emitted radio wave, when received, tells us nothing except that it is there. The very earliest radio converted such neutral waves into recognisable messages by keying the transmission on and off in the form of Morse dots and dashes. To transmit recognisable speech it is necessary to impose an additional oscillation on to the wave representing the physical wave-form of a human voice. By speaking into a microphone, the sound waves, moving in the air, are converted into an electrical signal voltage which fluctuates in response to the words spoken. This fluctuating voltage is then imposed on the outgoing radio waves so that the final transmitted signal has a volume, or amplitude, governed by the original speech-waves it carries. The process is reversed at the receiving end and, with the use of a loudspeaker, recognisable speech is heard. This modulation is achieved by altering the amplitude of the radio signal and is therefore known as amplitude modulation, or A. M. This is the most widespread and popular radio medium. After many years of experimental work, E. H. Armstrong managed to convince sufficient people, by the late 1940's, that another method of modulation called frequency modulation, using the very high frequency wave-band, was the answer to all forms of outside interference in reception, and to the gross over-crowding of the existing wave-bands. Technically he was correct, and eventually frequency modulation, or F. M. (better known as V. H. F.) came to stay. Instead of altering the amplitude of the outgoing signal, it affects the frequency itself by means of the audio signals from the microphone. The effect over short distances is very good: almost complete freedom from every form of interference. In addition, the new short wavelengths allocated were, and remain, uncrowded. V.H.F. radio operates largely by ground waves and is ideal for local broadcasting, since its effective range is only about 40-50 miles.

*Monitoring.* Systematic listening to radio (or TV) transmissions from other than one's own stations, in order to note and report on their content.

*Multiplex Transmission.* The sending out of more than one signal at the same time from the same transmitter.

*Negative.* Electrically speaking, the state of having an excess of electrons.

*Oscillation.* An electric current fluctuating, or alternating, periodically between two extremes of intensity.

In radio, it is the oscillatory energy that produces the emission of electromagnetic waves.

*Oscillator.* Device for generating an oscillating current, usually of high frequency.

*Positive.* Electrically speaking, the state of having a deficiency of electrons.

*Propagation.* The radiation of radio waves through space. In the earliest days, the pioneers had very few new words with which to describe what they were doing. So they fell back on existing terms—often with a somewhat "earthy" significance—giving them new meaning within the context of wireless: propagation, broadcasting, etc.

*Radar.* The term radar is derived from "radio detection and ranging." High frequency transmitters equipped with highly directional aerials send out short pulses of radio waves. If these hit a solid object (ship, aircraft, bird, building, etc.), some of the electromagnetic energy is reflected back to the aerial. This results in a signal being received as well as transmitted; when these are timed, it is possible to determine exactly how far away the reflecting object is. The signals can be presented visually on the screen of a cathode ray tube, so that the screen becomes an electronic "map," constantly changing as the objects being tracked move.

*Radiation.* The emission of radio waves from a radio station. Marconi used the term freely, sometimes calling his transmitter a radiator. Nowadays radiation has a further meaning, being the harmful rays that are given off by an atomic explosion.

*Radio Astronomy.* Radio waves emanating from space, beyond our own solar system, were first discovered in 1932, but the important science of radio astronomy did not really get under way until the late 1940s. Radio astronomy is a fairly new branch of radio knowledge, but it has already vastly increased our knowledge of the stars beyond our own sun. The signals from outer space are generated naturally by the stars and by the clouds of rarified, cold gas that fill vast regions of interstellar space. Linked with this study is radar astronomy, in which echo pulses are bounced back to earth from the moon, the planets, meteors, etc. These sciences do not replace ordinary visual or optical astronomy, but rather complement it. They involve the use of huge "radio-telescopes," like the famous one at Jodrell Bank. These are colossal, highly-sensitive receiving aerials which detect and interpret the radio emissions from distances that would have astounded even Marconi.

*Radio Frequencies.* These are usually higher than audio frequencies. Most radio transmission is confined to frequencies between approximately 150,000 cycles/second and 800 million cycles/second.

*Radio Telephony.* Radio transmission involving the direct use of the human voice.

*Receiver.* Any piece of radio apparatus that can pick up (or detect) radio frequencies and convert them into amplified, recognisable telegraphy, speech, music, sound or pictures. Marconi sometimes called his receiver a "resonator."

*Scanning.* The basic principle of television whereby a beam of electrons sweeps very rapidly over an optical image of the scene to be televised. This image is broken down into a series of horizontal lines, and electrical impulses corresponding to these lines are generated and transmitted via high frequency radio waves as television signals. The reverse process is used at the receiving end, with scanning used to reassemble the picture on the screen of a cathode ray tube.

*Scrambler.* Device which changes the frequency of a voice using a radio-telephone, so that only a receiver fitted with a reciprocal unscrambling device can receive an intelligible message, other listeners hearing only meaningless noises.

*Semiconductor.* Substance whose ability to conduct electricity falls halfway between the accepted good conductors and the recognised insulators. The electrons in a semiconductor are not free to move around but they can be persuaded to do so fairly easily. The primitive crystal, as used in a crystal set, was a form of semiconductor, but the most important ones are those used in the transistor to fulfil the functions of the valve, but at much lower levels of power consumption.

*Short Wave.* Radio wavelength from about 10 to 180 metres.

*Signal.* Radio wave carrying information (telegraphy, speech, music, sound or picture) impressed on it by means of modulation.

*Sky Wave.* Radio wave that reaches the receiver from the transmitter only after reflection from the ionosphere. See also *Ground Wave*.

*Static* (Atmospherics). Natural electrical disturbances in the earth's atmosphere, including lightning, tropical storms, etc. These cause unpleasant hissing, crackling or crashing interference on radio reception and a poor fuzzy picture on the television. This is due to spurious radio waves.

*Transformer*. Device for changing, or transforming, the power or voltage of an alternating current without affecting its frequency. Marconi used transformers, usually to increase, or step up, the voltage of the supplies he used. Transformers may also be used to step down, or reduce, a power supply voltage. All transformers work on the principle of induction, and the induction coil.

*Transistor*. Device used in electronics to amplify, detect, or produce signals. The operation of the device is based on the slight flow of current that can be induced in a semiconductor. It fulfils approximately the same function as the valve.

Transistors were not perfected until about 1949, and they have been undergoing development ever since. They now play a large and vital role in all forms of radio. Transistors usually consist of a tiny crystal or semiconductor, in which an impurity has been dissolved. Advantages of the transistor over the valve include its small size, the low power level at which it operates, the lack of heating required to operate it (used in valves to produce a flow of electrons), cutting out the warming-up period and heater "hum" experienced with valves. They also have a more or less unlimited life.

*Transmitter*. Any piece of equipment that can convert an ordinary alternating current into some form of modulated radio wave for radiation from an aerial.

*Triode.* A three-electrode, thermionic valve. The electrodes are the cathode, which produces a stream of electrons that flow to the anode through the grid, which is used to control the flow.

*Troposphere.* The lower part of the atmosphere, from ground level up to about eight or ten miles. Conditions within the troposphere have an effect on the behaviour of radio waves.

*Tuner.* Device that relates the receptive power of a radio receiver to the particular wavelength it is required to "listen" to. The "tuned circuit," which selects particular frequencies of radio waves from a large number of frequencies, is the basis of all modern radio receivers.

*Ultra Short Wave.* Radio wave between the longest microwave (about 30 centimetres) and the shortest short wave (about 10 metres).

*Valve* (Tube). A thin glass tube, or container, containing electrodes in a vacuum, or a gas. Electrons flow from the cathode, which is heated, to the anode. This flow can be controlled by grids, other electrodes, placed between the anode and the cathode. The invention of the valve first made possible the amplification of incoming signals, making them strong enough to operate a loudspeaker. The valve also made possible the process of modulation. It has now been largely superseded by the transistor.

*Video Tape.* The term video is used to denote the picture sections of a television as distinct from the audio sections, which deal with the sound. The video tape system permits the simultaneous recording of both picture and sound on a single magnetic tape, about two inches wide. This can be immediately played back through a television receiver, much the same as an ordinary sound magnetic tape can be played back through a tape recorder.

*Voltage.* A measure of the electromotive force, or potential, of an electric current. It is expressed in volts, named after the Italian pioneer scientist of electricity, Alessandro Volta (1745-1827).

*Watt.* The unit of electrical power.

*Waves.* Electromagnetic or radio waves. (See also *Carrier Wave*, *Daylight Wave*, *Ground Wave*, *Hertzian Wave*, *Long Wave*, *Medium Wave*, *Microwave*, *Sky Wave*, *Short Wave*, *Ultra Short Wave*).

*Waveband* (or *Frequency Band*). Group or section of wavelengths allocated to a certain purpose or type of transmitting station.

*Wavelength.* The distances between successive peaks of an S-shaped radio wave. Usually expressed in metres, it is directly related to the frequency of the radio wave by the speed of light.

# SOURCES OF THE ILLUSTRATIONS

*Frontispiece:* Guglielmo Marconi. Mansell Collection, London.

1 Marconi with his mother and brother Alfonso. Courtesy of the Marconi Company Ltd., Marconi House, Chelmsford, Essex.

2 Marconi and his apparatus in a lecture poster. Marconi Company Ltd., Essex.

3 Marconi's letter of introduction to W. H. Preece. Marconi Company Ltd., Essex.

4 Post office men examining Marconi's apparatus. Marconi Company Ltd., Essex.

5 Poldhu wireless station, 1901. Marconi Company Ltd., Essex.

6 Kemp, Marconi and Paget at Signal Hill. Mansell Collection, London.

7 Map of messages received by S. S. *Philadelphia*. Anne Cope.

8 Marconi in group at Glace Bay station, Nova Scotia. Marconi Company Ltd., Essex.

9 Handwritten extract from a Marconi lecture. Marconi Company Ltd., Essex.

10 Marconi outside the House of Commons, photograph by Sir Benjamin Stone, M. P. Mansell Collection, London.

11 Mr. Punch congratulating Marconi, from *Punch*, October 22nd, 1913. Mansell Collection, London.

12 Marconi in trenches at Monte Grappa. Marconi Company Ltd., Essex.

13 Dame Nellie Melba broadcasting a recital of songs. Marconi Company Ltd., Essex.

14 Marconi's second wife at a fancy dress ball. United Press International (UK) Ltd., London.

15 *Elettra* in Mount's Bay, Cornwall. Marconi Company Ltd., Essex.

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| Orrin E. Dunlap: | *Marconi, the Man and his Wireless* |
| Hannah Bellis: | *Edison and Marconi* |
| H. E. Hancock: | *Wireless at Sea* |
| Degna Marconi: | *My Father, Marconi* |
| Frances Donaldson: | *The Marconi Scandal* |
| David Gunston: | *Marconi, Father of Radio* |

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