Guglielmo Marconi and the History of Radio – Part II

by G. A. Isted, M.I.E.E.
Personal Technical Assistant to G. Marconi, 1926 – 1936

G. A. Isted was born in 1903 and joined the Marconi Company at Chelmsford in 1923. In 1926 he was transferred to G. Marconi's private laboratory in London. In 1929 he was sent to Italy as Marconi's personal technical assistant and participated in Marconi's microwave experiment. When hostilities broke out between Italy and Abyssinia in 1935, he was recalled to England where he joined the staff of T. L. Eckersley who was studying radio wave propagation, mostly at Gt. Baddow. During World War II, he was in charge of the RAF section of the Inter-Services Ionospheric Bureau based at Great Baddow. Subsequent to Eckersley's retirement, he became Chief of the Marconi Radio-wave Propagation Group. He was largely responsible for the success of the nationwide coverage of the Independent Television Authority Band III television service. He retired in 1969 after 46 years with the Marconi Company.

In Part I of this paper (GEC Review Vol. 7, No. 1) the early history of radio was outlined, along with Guglielmo Marconi's crucial pioneering rôle. Part II now covers highlights of his subsequent career, including transmission across the Atlantic, the saving of 700 lives after the 'Titanic' disaster, and blind navigation using microwaves.

Highlights of Marconi's Career

In every person's career there are episodes which stand out in one's mind like milestones along a road. Marconi had an abundance of them and it certainly would have been difficult, even for one who has studied his work in detail, to single out those which were more important than the rest.

If Marconi himself had been asked to name just four of his many achievements that gave him the greatest satisfaction, he would undoubtedly name as his first choice his epic experiment in which he first succeeded in receiving wireless signals across the Atlantic Ocean in 1901. The next would be the part that his wireless played in saving the lives of 700 survivors from the S.S. 'Titanic' disaster in 1912. His discovery of the daylight short wave in 1923 would have been a must. His final choice would have been his last large-scale experiment carried out in the Mediterranean in 1934 when, with the aid of microwaves, he was able to demonstrate that a ship could be manœuvred into port in conditions of zero visibility.

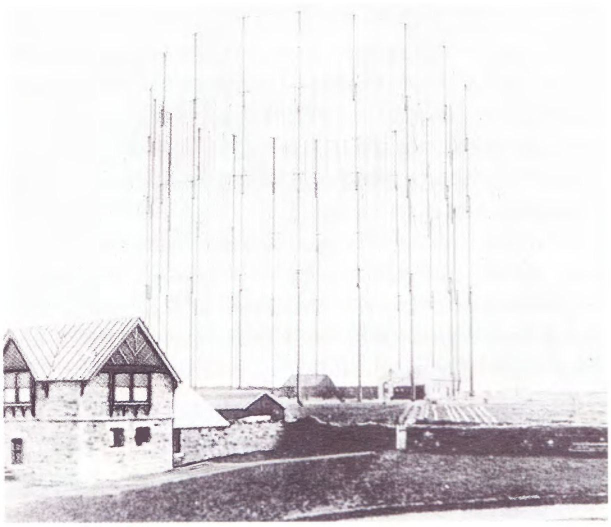
Transmission Across the Atlantic

Marconi's tests in 1900 had not indicated that there was any limit to the distance that wireless waves could be transmitted; the limit always seemed to be dictated by restrictions imposed by his apparatus. Characteristically, therefore, he thought big and decided to build the largest power-house spark transmitter (25 kW input power), with a view to establishing exactly what the limit was – if there was, in fact, a limit.

Professor J. A. Fleming was engaged in early 1900, to design and build this colossus, which was to be installed at Poldhu on the south coast of Cornwall. From here, various places at differing distances could be chosen where observations would be made (figs. 1a–c). The transmitter was operating in the spring and summer of 1901 and it was quickly found that strong signals were received at Crookhaven, South Ireland, 250 miles from Poldhu, in spite of the intervening bulge of the Earth. Marconi reasoned that if signals were strong at 250 miles, there seemed to be nothing to stop the transmission of wireless waves across the Atlantic Ocean – after all, it was a little less than ten times the distance already covered!

In spite of protests from the Board of his Company and the derisory comments from 'the men who knew' that such a thing was impossible, Marconi embarked on the S.S. 'Sardinian', with his assistants Kemp and Paget, and sailed for St. John's, Newfoundland. Upon arrival, they housed themselves in a disused military hospital on top of the highest hill and set about assembling their receiving apparatus. In the end, because of equipment difficulties, the receiver was modified into the simplest arrangement possible. It consisted of a long wire held aloft by a kite as an aerial (fig. 2); the aerial was connected to a coherer and a pair of headphones and, finally, to an earth connection. What wavelength was used no one seems to know; Professor Fleming admitted he did not know. It was not until 1905 that he developed a device for measuring wavelength which he called a cymometer.

Marconi's presence at St. Johns aroused much interest and journalists and sightseers were there in plenty (fig. 3). After a period of listening there came the day, December 12th, when, at 1.30 p.m., Marconi was convinced that he heard the pre-arranged signal, three dots forming the Morse letter 'S', repeated. Kemp, his assistant, was also convinced that he heard the signal. Transatlantic



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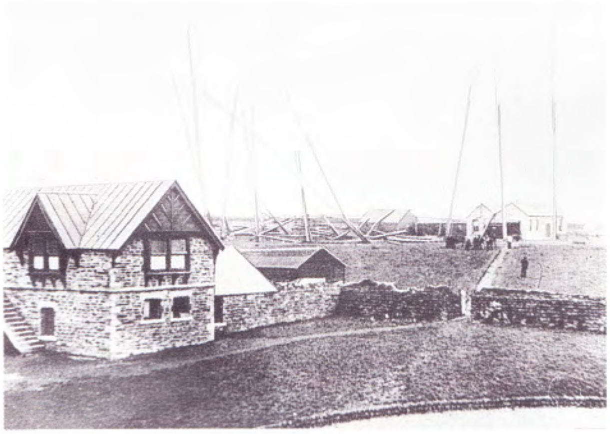

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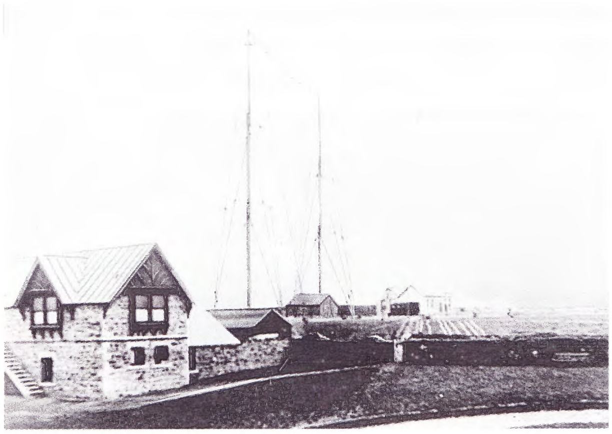
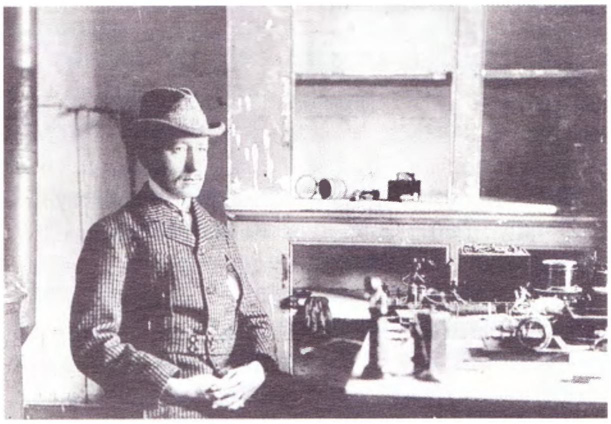


c)

1 a) ***The circular antenna array at Poldhu for the transatlantic test. This was blown down in a gale in September 1901. The array comprised wire and 20 wooden masts, each 200ft high.*** **b)** ***View of the antenna at Poldhu after the gale, and*** **c)** ***Poldhu wireless station in December 1901, showing the antenna system used for sending the first wireless signals across the Atlantic from England to Newfoundland***

2 ***Raising a kite at St. Johns, Newfoundland, in December 1901 for the first transatlantic wireless experiments. Marconi is on the extreme left.***



3 ***Marconi at St. Johns', Newfoundland, in December 1901 with the apparatus used to receive the first wireless signal across the Atlantic from Poldhu, Cornwall***

communication had been achieved by wireless telegraphy for the first time!

Why send only the letter 'S' – just three dots? According to Marconi, if dashes had also been sent, the dynamo supplying the power at Poldhu would have disintegrated under the increased load!

When news of Marconi's success appeared in the world press, it caused a major stir. Many people were excited at the prospects it offered but others, especially 'the men who knew', thought that Marconi was mistaken. It just could not be true, they said.

The arguments have raged ever since. Did Marconi hear three dots or didn't he? So far as Marconi was concerned he proved – two months later, during trials on the S.S. 'Philadelphia' across the Atlantic – that signals could be heard and recorded at comparable distances. The tape records of these trials were signed by the ship's captain as evidence of their authenticity.

A further question that raised doubts at the time was: why did not Marconi repeat the test the next day? The answer to that is simple. The

Anglo-American Telegraph Co. issued a writ prohibiting Marconi from carrying out further tests! They were in no doubt about the authenticity of the achievement.

At the Marconi Centenary Celebrations held at the Institute of Electrical Engineers in 1974, J. A. Ratcliff described[1] how he and a body of radio scientists and mathematicians had recently re-examined the conditions of the tests and had come to the conclusion that Marconi had not deluded himself on that day in 1901 – it all depended upon which wavelength was considered. This was seventy-three years after the event!

The rank and file of the Cable Company obviously took the news of Marconi's success not too seriously as the following light-hearted exchange of signals at Christmas, 1901, clearly indicated.

Christmas greeting from the cable terminal at North Sydney to its companion terminal at Liverpool:

Best Christmas greetings from North Sydney,
Hope you are sound in heart and kidney,
Next year will find us quite unable
To exchange over the cable.
Marconi will our finish see,
The Cable Co's have ceased to be,
No further need of automatics
Retards, resistances and statics.
I'll then across the ether sea
Waft Christmas greetings unto thee.

Reply from Liverpool to North Sydney:

Don't be alarmed, the Cable Co's
Will not be dead as you suppose.
Marconi may have been deceived,
In what he firmly has believed.
But be it so, or be it not,
The cable routes won't be forgot.
His speed will never equal ours,
Where we take minutes, he'll want hours.
Besides, his poor weak undulations
Must be confined to their own stations.
This is for him to overcome,
Before we're sent to our long home.
Don't be alarmed, my worthy friend,
Full many a year precedes our end.

And again from North Sydney to Liverpool:

Thanks old man, for the soothing balm,
Which makes me resolute and calm.
I do not feel the least alarm,
The signal S can do no harm,
It might mean sell to anxious sellers,
It may mean sold to other fellers.
Whether it is sold or simply sell,
Marconi's S may go to – well!

It is not difficult to imagine Marconi's elation at his success, and throughout his career he kept that episode well in mind as the greatest instance when the wise men who 'knew' based their reasoning upon inadequate data.

Thomas Edison was one of the famous scientists who believed that Marconi had successfully received wireless waves across the Atlantic Ocean and, when the American Institution of Electrical Engineers provided a banquet in Marconi's honour at the Wardorf Astoria Hotel, New York, on January 13th 1902, he sent the following telegram:

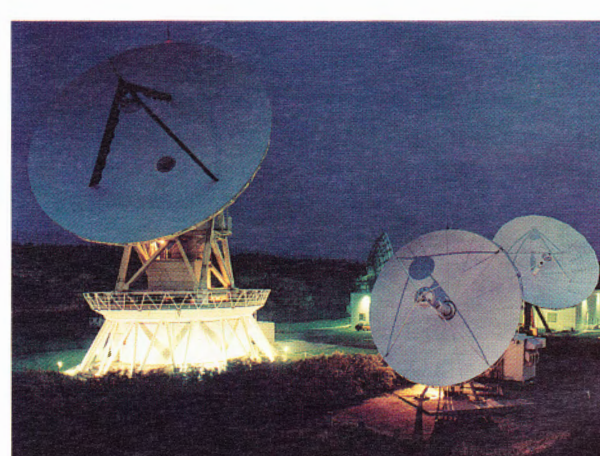
'I am sorry that I am prevented from attending your dinner tonight especially as I should like to pay my respects to Marconi, the young man who had the monumental audacity to attempt and succeed in jumping an electric wave clear across the Atlantic Ocean.'

There was fierce competition between the wireless and cable communication interests during the following years. With Marconi's introduction of the short-wave beam system, wireless started to prevail. Ultimately, however, they were merged sensibly into a new company calling itself 'Cables and Wireless Ltd.', in 1929.

A modern satellite communication dish, supplied by GEC-Marconi Communications Ltd. to Cable and Wireless p.l.c. is shown in fig. 4.

The Titanic Disaster

The first life-saving possibilities of wireless were demonstrated in 1899 when a wireless message was received from the East Goodwin lightship – which had recently been equipped with Marconi wireless apparatus – that she had been rammed



4 ***Mercury Communications Systems satellite communications ground station at Whitehill, Oxfordshire, for which Marconi has supplied antennas and electronic equipment as prime contractor***

during dense fog by the steamship 'R.F. Matthews'. A request was made for the assistance of a life-boat.

In 1911, McLaren and Battle gave a lecture to the Institute of Marine Engineers on the subject of Wireless Telegraphy at sea[2]. They stated at one point:

'As regards marine engineers who are going to sea, the presence of the Marconi apparatus gives us a certain amount of confidence in our work of taking charge of ships away from home. We feel that with the Marconi on board we are safe. It has become an important part to the life-saving service.'

Within a year how true that was going to be! McLaren and Battle continued:

'This has been demonstrated by the following announcement which recently appeared in "Telegraph and Telephone Age" : "A rough calculation has been made recently as to the success and value of assistance rendered by wireless telegraph to ships at sea in the saving of life and it is estimated that 3 000 persons owe their continued existence at the present time to the help rendered by wireless telegraphy."

That was up to 1911! It is interesting to observe that, when they referred to the wireless apparatus, they called it 'the Marconi' in the foregoing excerpt.

By 1910, it was mandatory to have wireless telegraph apparatus installed on every large ship, with a competent telegraphist in attendance. Not all ships had enough telegraphists, or 'sparks' as they were collectively called, to cover a continuous twenty-four hour watch.

The need for more than one telegraphist was made crystal clear at the time of the White Star Line steamship 'Titanic' disaster. The 'Titanic', the pride of the British mercantile fleet, left Southampton on the morning of April 10th 1912, in perfect weather, on her maiden voyage across the Atlantic to the United States of America. Up to that time she was the largest ship ever to be built, having a displacement of 46 000 tons and extending 900 feet in length. She was not the fastest ship, but she was the most luxurious one the world had ever seen and could accommodate 2 000 passengers.

The 'Titanic' at the time of her launch was described as 'unsinkable'.

The ship carried two 'sparks'; Chief Telegraphist John Phillips and Second Telegraphist Harold Bride. Their wireless installation was the very latest in design and was one of the most powerful in those days, having a range of 350 miles by day and much more at night.

On Sunday, April 14th, as the 'Titanic' was approaching Cape Race, Bride received a wireless signal in the afternoon from the S.S. 'Californian' to say that icebergs had been sighted in the vicinity. The signal was passed to Captain Smith, the 'Titanic's captain, but for some reason which does not have a satisfactory explanation, he held the ship's speed, it is said, to 22 knots – icebergs or no icebergs. His ship was unsinkable.

Just before midnight, the passengers were singing and dancing with the bands playing after their good evening dinner; then the biggest maritime disaster up until that time befell the 'Titanic', but few at the time knew anything of it. There had been just the slightest jolt and the engines stopped. The 'Titanic' had struck an iceberg.

The only persons who really knew what had happened were those of the crew in No.10 stokehold who had seen the whole side of the ship torn apart beneath the water-line, followed by seawater cascading into the ship. Even Telegraphist Phillips, who was then on watch, was unaware that anything serious had happened and continued his routine work.

The Captain made his way to the wireless cabin and said 'We've struck an iceberg – send a wireless call for assistance'. This was thirty-five minutes after the iceberg was struck. Phillips tapped out the recognized Marconi distress call, CQD, followed by the 'Titanic's call-sign, MGY, and the message that an iceberg had been struck, and that assistance was urgently required. Subsequently he added the ships position as 41–46N, 50–14W. After a while, he included the internationally-recognized distress call, SOS, in his repeated calls.

Ships began to answer the call for help and themselves relayed the 'Titanic's call to those ships which had not received it directly.

The first to answer was a German ship, the 'Frankfort', which was about 150 miles away. Next came a call from a very small vessel, the 'Carpathia', having Marconi Telegraphist Cottam as the 'sparks'. She was about 60 miles away. She replied that she had turned about and was heading for the scene of the disaster at full speed. To steam at full speed in darkness knowing that icebergs were floating in the vicinity was a very risky procedure and the captain displayed great courage.

Other ships within wireless range – the 'Caronia', 'Virginian', 'Olympic', 'Baltic' and 'Birma' – all answered that they were steaming to the stricken vessel.

There was one ship, only 10 miles from the 'Titanic', which was large enough to have taken care of every person on board. She was hove-to because of the danger from floating ice. Her lights could be seen from the decks of the 'Titanic' but her wireless cabin was deserted, her wireless dead –

the single 'sparks' on board had gone to bed after a heavy day of operating. This was the same ship, the 'Californian', which had warned the 'Titanic' that icebergs had been sighted during the Sunday afternoon.

Meanwhile, Captain Smith knew that the Titanic could not keep afloat much longer and gave orders to abandon ship. As many lifeboats as could be launched were filled to capacity with scantily clad men, women and children, many of them injured, some were dying, and all were very wet and chilled in the ice-cold night air.

After a while the power failed on the 'Titanic' and the main wireless apparatus became useless. Phillips then operated the battery-driven emergency transmitter which enabled him to keep in contact with Cottam on the 'Carpathia' for some time. Cottam noted that, at 1.17 a.m., the 'Titanic' signals faded and abruptly stopped. The 'Titanic' was at the bottom of the sea, taking 1 500 souls with her.

Chief Telegraphist Phillips died by his wireless cabin, although he had been told by Captain Smith to save himself if he could. Telegraphist Bride had already gone over the side having done all he possibly could.

The little 'Carpathia' arrived at the scene a few hours later and in the dawn light located wreckage and then the lifeboats. She was able to rescue 700 survivors, thus preventing their deaths from exposure. Wireless telegraphy undoubtedly made the rescue possible.

Great confusion arose in New York because the wireless installation on the 'Carpathia' was unable to communicate directly with a shore station, but had to rely on his messages being relayed from ship to ship, and then to shore; inevitably, only exaggerated and distorted news reached its destination.

Telegraphist Bride had been rescued and, although he had been injured, made his way to the wireless cabin to help Telegraphist Cottam with his mammoth task of transmitting continuous news of survivors to the 'Olympic' for onward transmission to shore.

Marconi happened to be in New York when the disaster occurred and as soon as the 'Carpathia' docked with her human cargo, he immediately made his way to the wireless cabin to greet two tired men, Cottam and Bride. He was probably the first to obtain authentic news of the events which had, literally overnight, increased the 3 000 persons saved by wireless telegraphy, mentioned by McLaren in 1911, up to at least 3 700.

As Marconi came down the gang-plank to the quay he very humbly remarked: 'It is worthwhile having lived to have made it possible for these people to have been saved'.

That same day the newspapers bore headlines proclaiming that Marconi and his wireless had been the means by which 700 souls had been saved. In the House of Commons the Postmaster General, Herbert Samuel, in announcing the news of the disaster to a shocked House said: '.... That so many are alive today is due to one man, and one man alone, Mr. Marconi'.

The survivors themselves were moved to present Marconi with a gold medal, suitably inscribed by the noted sculptor, Poalo Trabetzkoz, as a measure of their gratitude for their deliverance.

The New York Electrical Society held a meeting on April 17th at which Marconi was asked to talk about 'The Progress of Wireless Telegraphy'. Such was the tumultuous reception he received that it was some time before he could begin to speak.

The 'Titanic' disaster threw into sharp relief the need for higher-powered transmitters so that no ship should feel isolated from shore. It also emphasized that some means must be found to avoid the 'Californian's calamitous silence. Marconi already had ideas of an automatic alarm apparatus which would alert the telegraphist to distress signals while he was on routine work or off duty. It was to be 1927 before it was mandatory to install such apparatus on ships.

The 'Titanic' disaster and the lives that were saved by wireless would surely have been one of the many milestones in Marconi's mind, for in 1932 he wrote:

'The greatest value of wireless, in my belief, is still demonstrated by its utility at sea.'

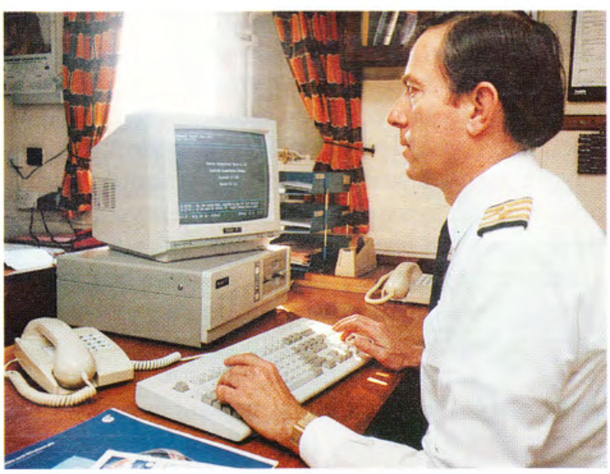
Fig. 5 shows modern marine communications equipment.

The 'Daylight' Short Wave Discovered, Mislaid, Rediscovered

In a survey paper which Marconi read to the American Institution of Electrical Engineers and the Institute of Radio Engineers at New York in June 1922, the title of which was simply 'Radio Telegraphy'(3), he said at one point:

'Some years ago, during the war, I could not help feeling that we had perhaps gotten rather into a rut by confining practically all our researches and tests to what I may term long waves, or waves of some thousands of feet in length, especially as 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'.

a)

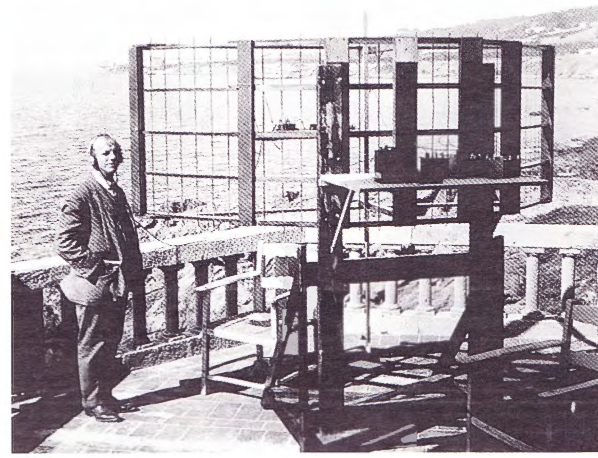


b)

5 a) ***Modern ship's radio room fitted with GEC-Marconi Communications Ltd. 'Oceanlink' series communications equipment, and*** **b)** ***radio operator using GEC-Marconi Communications Ltd. 'Oceanray 2' maritime satellite communication system***

This was probably a hint that he was working on ways and means for 'getting out of the rut', as he called it. In the paper he mentioned some tests which he and his assistant, C. S. Franklin, had carried out in Italy during the war. These were directed towards making a communication system that had a limited range, and which would be difficult for an unfriendly power to intercept. He described how, in 1916 (see fig. 6), he developed a spark system operating on a wavelength of 2 to 3 metres having a directional, or 'beam', aerial in just such a manner as Crookes described in 1892.

Marconi could very well have spoken about the short-wave experiments that had already been carried out the year before over the North Sea by Franklin but, typically, he chose to say nothing about this work because some very odd results were being obtained, which he could not explain.



6 ***C. S. Franklin in Italy in 1916 carrying out work on very short waves. This work led to the Marconi–Franklin short-wave beam system in the 1920s.***

These experiments had been carried out on wavelengths between 15 and 100 metres – very much shorter than the wavelengths then currently in use – across a series of routes between Zandvoort in Holland and Southwold, Hendon and Birmingham in England. It is now known that it would be difficult to imagine a more complicated and unpromising network of test routes over which to study the behaviour of radio waves. The network comprised 'all sea' routes, 'all land' routes, and 'mixed land and sea' routes, each route having its unique mode of transmission over the surface of the earth and sea.

An unpublished report of Franklin's to the Marconi Technical Board summarized the results obtained. He described, in particular, a remarkable and unexplained difference in the behaviour of signals in the 30 – 60 metre band over the different routes. Quoting from the report, Franklin said:

> 'Whereas at Southwold, about 110 miles from Zandvoort, the signal at night is much greater than the day strength; at Birmingham, however, 282 miles from Zandvoort, the day strength appears normally to be greater than that at Southwold, while at night it is impossible to get any sign of the signals.'

Experience had shown in the past that signal strength on long-wave transmissions was greater at night. Here was a complete reversal of the behaviour of long waves. Something needed an explanation!

With our knowledge today there would be little doubt that the day signal at Birmingham from Zandvoort was being reflected downwards by the upper layers of the ionosphere.

Incredible as it may now seem, Marconi actually had the discovery of the 'daylight' wave within his grasp in 1922 – but failed to recognize it as such! Notwithstanding Marconi's lack of appreciation of the evidence of the tests, it was to take him only a short time to rediscover this much wanted 'daylight' wave.

In May 1922, just before he read his paper in New York, Marconi arranged with Franklin to make a detailed and careful examination of the transmission characteristics of all waves between 15 and 100 metres at differing distances. The transmitting station was to be at the historic site of Poldhu in Cornwall. Marconi's steam yacht S.Y. 'Elettra' (see later) was to be equipped with suitable receivers. They agreed that, as it was relatively easy to construct a beam aerial for 97 metres and that until more apparatus became available, the tests would be limited to that wavelength.

In the summer of 1923, Marconi took the 'Elettra' on a cruise to the Cape Verde Islands, off the west coast of Africa. Anchored at San Vincenzo, a distance of 2 500 miles from Poldhu and an all-sea route, he commenced a series of listening and measuring tests. He found that, at that distance, the signal was much better than any signals he had received over a comparable distance from high-power long-wave transmitters.

Nevertheless, as with long waves, the signals disappeared during the daylight hours. However, Marconi observed that the signals lasted for a time after sunrise at Poldhu and that they became audible again before darkness came at the Cape Verde Islands. That observation led him to suspect that some new phenomenon was operating on the 97 metre wavelength.

At the end of a report to the Directors of the Company on the results of the S.Y. 'Elettra's receiving tests, dated 12th June, 1923, Marconi wrote: 'I have little doubt, however, that with our present knowledge, and with stations using only about 12 kW, it would be possible to maintain, daily, a 10 to 14 hours communication service between Europe and Brazil, and perhaps with the Argentine'.

Upon his return to England, Marconi arranged for a further series of experiments to test and compare the 97 metre signals with other wavelengths down to 30 metres.

In the meantime, Marconi persuaded the British Government that the Imperial Communications chain of long-wave stations which the Company was about to supply were really obsolete before they were installed, and that the short-wave technique was the most economical and efficient system to employ.

In September 1924, Marconi continued his short-wave experiments when he cruised in the 'Elettra' through the Mediterranean. At the coast of Syria the yacht was anchored in the harbour of Beirut, a distance of 2 400 miles from Poldhu, mostly over land. Throughout the listening schedules, the astonishing observation was made that the 32 metre signal was operating all the daylight hours. It was clear, therefore, that if the wavelength was changed daily from 97 metres to 32 metres, a near 24 hours communication circuit was possible.

When Marconi returned to England, he initiated a schedule of transmissions on 32 metres from Poldhu and requested reports of reception. Swiftly came back reports from Argentina, Brazil, Canada and the United States of America that, at the appropriate times the daylight signal was being well received. Australia at the antipodes reported 23 hours out of 24 of good signals.

During the ensuing tests, it was established that other short waves were superior to the 97 and 32 metre waves. Marconi had achieved his ambition and, as he would have said, he'd 'gotten wireless out of the rut'. It was now up to his manufacturing organization to exploit the new and revolutionary techniques.

Marconi's success with short waves had astonished the scientists who then became very busy trying to explain how these things were possible. It was E. V. Appleton who proved conclusively the existence of the ionosphere, as well as measuring its height. He identified two reflecting regions, the first he named the E-layer in 1924, and a higher region he found two years later which he named the F-layer. Marconi had outstripped 'the men who knew' once more!

By 1926, by the use of the new short-wave technique and with the great help of Franklin's 'beam' aerials, the first of the Empire chain of two-way telegraph stations came into being between England and Canada. This was followed by many others to all parts of the Empire, each capable of passing telegrams at the rate, normally, of one hundred words per minute.

Franklin's 'beam' aerials, being highly directional, eliminated the worst of the effects of interference from lightning storms; but there remained another serious problem peculiar to the use of short waves. Marconi observed at the very beginning of his short-wave experiments that the signal intensity was constantly varying. The effect was commonly called 'fading' and, as time went on, it became understood that it was caused by the signal arriving by more than one route. When these signal components arrived out of step, the resultant signal was caused to 'fade' or, in extreme cases, the signal components could cancel one-another out and introduce what operators called a 'drop-out'. These drop-outs might last a fraction of a second, but when telegrams are being passed at one hundred words a minute it is a serious matter.

The odd thing about this fading was that two receivers spaced a short distance apart did not suffer from the effect simultaneously. There was in fact a 'space diversity'. An elaborate investigation into space diversity was carried out jointly by engineers of the Marconi Company and engineers of the B.B.C. in 1928–1930. The site chosen was on Lord Rayleigh's Estate at Terling, near Chelmsford. For the investigation, three receiving aerials were spaced one mile apart alongside the straight portion of the Witham Lane, in line with the United States station of Schenectady, which broadcast programmes on a wavelength of 21.96 metres. The signals from each aerial were combined on the centre site and the resultant signal was judged as to whether it was of sufficiently good quality to allow it to be rebroadcast. The results of the investigation were considered satisfactory, as the effects of fading were reduced to a minimum.

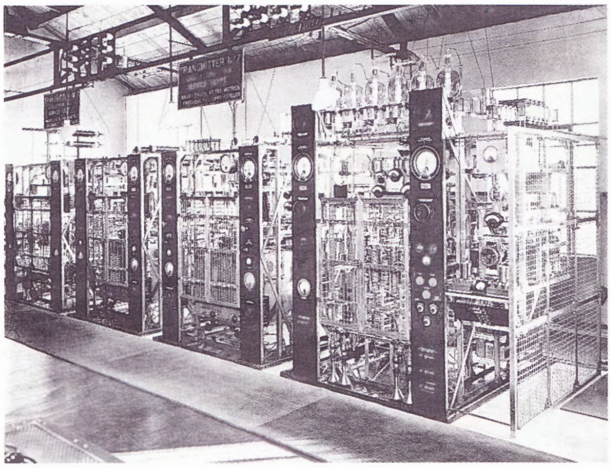
Marconi was also working on the problem of short-wave fading, but from a different point of view. He had observed that the fading was not coincidental on slightly differing wavelengths; this effect became known as 'frequency diversity'. In the seclusion of his private laboratory in Room 31, 3rd Floor, of Marconi House in London he set about designing a revolutionary system of communication. Marconi called it the Multiplex System. This system permitted three channels of communication – two telegraph and one telephony – to be superimposed onto a single transmitter. These three channels were separated at the receiver and transferred individually over land-lines to their respective destinations.

An ingenious method for the almost complete elimination of fading was employed for both telegraphy and telephony. The telegraph anti-fading device was based on the frequency diversity properties of short waves. The equivalent of sending the same message by two transmitting stations on two slightly different wavelengths was obtained by modulating the transmitter with frequencies of the order of 7 and 9 kHz, thus producing, side-bands of 14 and 18 kHz separation, respectively. At the receiver, these side-bands were separated and their respective channels recombined.

In the case of the telephone channel, situated between the upper and lower side-bands, the fading signal was used to operate a device called an 'automatic volume control', which maintained, by means of an electromechanical device, a constant level of signal to a telephone subscriber.

It has been said of Marconi that in all his experiments he 'thought big' – his Multiplex System of communication was a classic example that he actually did! The receiver had seventy-two valves, or 'tubes', housed in thirty double-screened copper boxes each having a capacity of three cubic feet, all supported on a massive angle iron frame weighing, in all, over a ton. The occupants of the floor beneath Room 31 heaved a sigh of relief when, finally, the day came for the receiver to be transported to its testing site at the Bridgwater beam station in Somerset (fig. 7)!

The system was put through its paces on March 1st 1929, when an important demonstration was staged between Bridgwater and Canada. It was witnessed by Sir Robert Donald, Chairman of the British Imperial Wireless Telegraph Committee,



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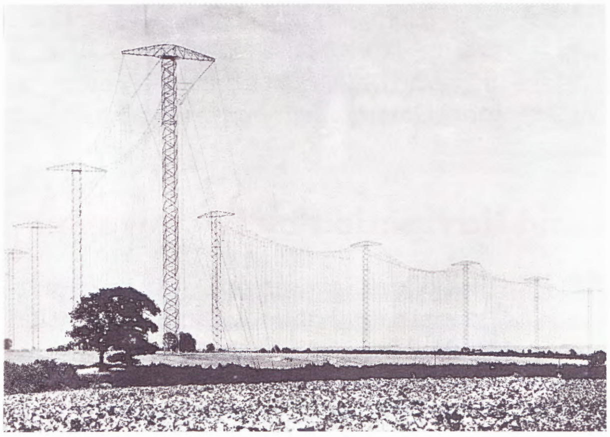


b)

7 **a)** ***Four panel short wave beam transmitter operating on 37 and 21 metres used for transmission to Egypt at the Dorchester beam station in 1930, and*** **b)** ***Antenna system at the beam radio station, Bridgwater in 1926***

Sir Basil Blackett, Chairman of the newly organized Imperial Communications Company, and other important people. Describing the demonstration, Sir Robert wrote:

'We were witnessing the successful demonstration of transmitting speech over a distance of more than 3 000 miles on the same wavelength simultaneously with two wireless telegraph messages. While we were using the desk telephone in the office of the station, the tape was running off written telegraphed messages in the operating room at the rate of hundreds of words a minute. These were being relayed to London without interruption. The invention is a unique combination of efficiency and economy. The system may be incorporated in all 'Beam' stations on the Imperial Chain, avoiding the necessity for new stations for telephonic communication.'

'The advantages of the Marconi Multiplex System, as it is called, are many. It is more efficient and incomparably cheaper. It does not involve the reconstruction of stations. It enables a short wave to be used. There is great economy in power; and there is almost complete secrecy. No one could have listened to our conversation except through a similar installation. What is being accomplished on the Canadian circuit can be carried out between other parts of the Empire. Already an apparatus is being made for the South African Beam station. The universal adoption of the system would enormously cheapen telephonic communication throughout the Empire.'

This opinion of the Multiplex System from an independent observer such as Sir Robert Donald, whose experience as Chairman of the Imperial Wireless Telegraphy Committee makes his views of unusual weight, should have been of the greatest value to all who are interested in the establishment of wireless telephone services over long distances. It was not to be though. The system seemed to be incompatible with the interests of the new merger of Cables and Wireless in 1929. A modern HF sound broadcast transmitter, made by GEC-Marconi Communications Ltd. for the BBC, is shown in fig. 8.

Blind Navigation by Microwaves

In 1928 the Italian Government, at last recognizing that Marconi's reputation and influence would be a most valuable political asset at that time, set about creating a situation in which permanent residence in Italy would be an attractive proposition to him.

So it happened that Marconi was given the responsibility of founding the Italian Research Council and became its first President. In 1929 the hereditary title of Marchese was conferred upon him by the King of Italy, and in 1930 he was nominated President of the Italian Royal Academy.

8 ***One of two 500kW HF sound broadcast transmitters installed at Rampisham, Dorset, for the BBC by GEC-Marconi Communications Ltd.***

It is not difficult to understand that Marconi was in a unique position. It was, perhaps, an understatement when he said about his personal circumstances: 'I enjoyed special facilities and was afforded every possible assistance and encouragement by the Italian Government'. The Italian Government was therefore most enthusiastic when Marconi expressed the wish to continue his wireless experiments in Italy.

Over the years Marconi had been obsessed with the fear that, having commenced his experiments with wireless on a wavelength of 30 centimetres in 1894–6, he had perhaps missed something important by allowing himself to be deflected from fully exploiting them by taking the slippery slope to longer and longer wavelengths in order to achieve greater and greater distances of practical communication. As an example, in the paper he read before a radio audience in New York in 1922[3], he said:

'The progress made with the long waves was so rapid, so comparatively easy and so spectacular, that it distracted practically all attention and research from the short-waves and this, I think, was regrettable, for there are very many problems that can be solved and numerous most useful results to be obtained by – and only by – the use of the short-wave system'.

Marconi, probably remembering that he had consigned to the scrap-heap his parabolic reflectors for use with the 30 centimetre wavelength decided to re-open those early experiments where the use of that kind of reflector would again be necessary.

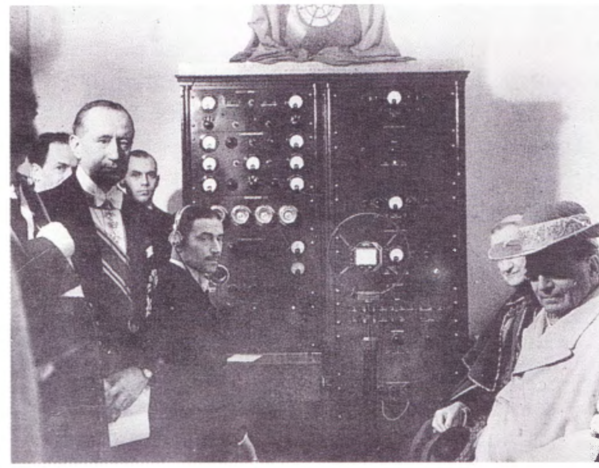
In 1932, after two years of experimentation, he gave an account of his work in a paper he read to the Royal Institution in London(4), where he described the work he had recommenced on wavelengths of the order of 50 centimetres. He first of all described the difficulties under which his new experiments were carried out because of the absence of those facilities, or 'tools of the trade', that are now available to the modern experimenter. There were no radio devices for the measurement of power, signal intensity or indeed wavelength itself. This fact explains the absence of the precise measurements to which we have become accustomed in recent years – it may serve also to enhance his technical achievements.

It was with crude and simple apparatus, which he had designed, that Marconi set out supremely confident that he would, yet again, confound the false prophets of the day who were of the opinion that transmission of his microwaves beyond the horizon was impossible. In the Royal Institution paper he said:

'Long experience has, however, taught me not always to believe in the limitations indicated by purely theoretical considerations or even by calculations, for these – as we well know – are often based on insufficient knowledge of all the relevant factors, but, in spite of adverse forecasts, to try out new lines of research, however unpromising they may seem at first sight.'

By 1932, Marconi was able to demonstrate a microwave two-way telephone system across the Ligurian Bay in the Mediterranean. The two terminals were situated one at Santa Margherita the other at Sestri Levante, a distance of 12 miles. The demonstration so impressed the Vatican Authorities that Marconi was requested to install a similar system between the Vatican City and the summer residence of His Holiness the Pope at Castel Gandolfo. The Vatican installation was inaugurated by His Holiness in February 1933 and is recognized as the first microwave telephone subscriber link in the world (figs. 9a and 9b).

Marconi was satisfied that he had sufficiently demonstrated the usefulness of microwaves for relatively short communication links, and he was content to leave it to his commercial organization to develop the idea. His ambition was clearly to break down the barriers which appeared to him to be imposing an unreasonable limitation upon the transmission of microwaves over substantial distances. With this in mind, and disregarding the opinion of the wise men who 'knew' that microwaves could not be transmitted beyond the horizon, he set about studying in more detail the laws governing their transmission characteristics over greater and greater distances. In this extended work the use of Marconi's yacht, the S.Y. 'Elettra',



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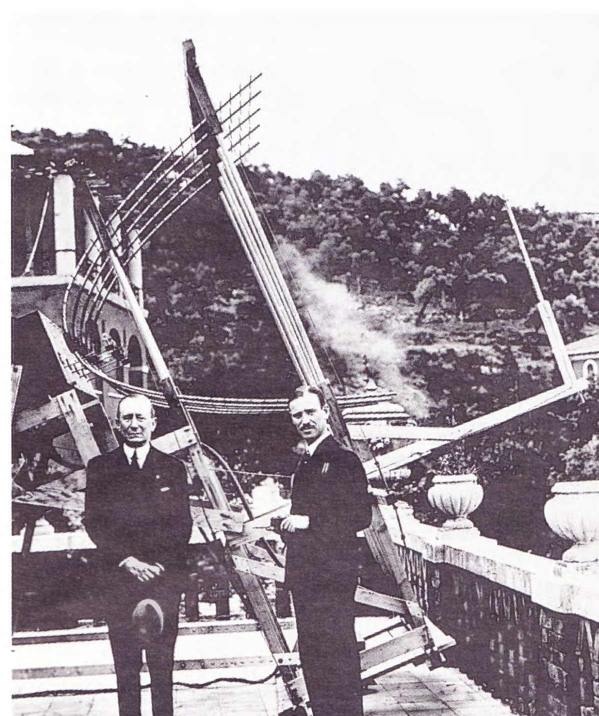

b)

9 a) ***Inauguration of the first microwave telephone service between the Vatican and Castel Gandolfo, the Pope's summer residence. On the right is His Holiness the Pope, Pius XI, with Cardinal Pacelli (who became Pope Pius XII) by his side. On the left stands Guglielmo Marconi, G. A. Mathieu (wearing headphones), and Gerald Isted in the background – both assistants of Marconi, and at the extreme left in the background is Padre Gianfranceschi, Director of the station.*** b) ***Part of the microwave radio link, with Marconi on the left and Mathieu***

was invaluable and, with it, signals were received over routes that were several times the distance of the horizon. On one such test, a distance of nine times the optical range was easily achieved.

It was typical of Marconi that he should follow an Easter-time custom in Italy to invite the church dignitaries to attend the yacht 'Elettra' to bless his family, his yacht, and the experimental work he was doing. The local Cardinal came with his attendants, starting at one end of the yacht sprinkling holy water on this and that, with an olive branch. He finally ended up at the wireless cabin where Landini, a wireless operator, and the writer were waiting. Landini fell to his knees to kiss the ring on the Cardinal's finger and the same was offered to the writer who, not going on his knees to any man, just shook his hand. The Cardinal continued sprinkling with his olive branch until they were due to leave the cabin, but not before giving the writer a very adequate dose of water as he left the cabin. Marconi came to the rescue and explained that the writer was an 'ingegnere Inglesi' !

Marconi made no secret of the fact that he hoped one day, with improved equipment, to find evidence of an elevated layer which would reflect microwaves in a similar fashion to the reflection of longer wavelengths by the ionosphere. Accordingly, it was routine procedure to determine the best vertical angle of transmission by tilting the parabolic aerials upwards in prescribed stages. His most ambitious tests in this respect were carried out between an extinct volcano, Rocca di Papa, near Rome, and the 'Elettra' anchored in the harbour at Venice – a distance of 300 miles. The experiment failed, then, partly because of insensitive apparatus. It is interesting to note, though, that Marconi's intuition was uncannily correct, for, thirty years or so later, communication links operating on slightly shorter wavelengths were installed between the North Sea oil rigs and the mainland, at distances approaching 200 miles, utilizing the so-called tropospheric scatter as the medium.

Throughout his career Marconi was always seeking ways and means of ensuring the safety of ships at sea. This urge was particularly keen while he was investigating the possibilities of utilizing microwaves, and it was in the field of marine navigation by microwaves that he gave a most spectacular demonstration which, sadly, was also to be his last.

In 1934, Marconi conceived of the idea of guiding a ship through a narrow entrance to a harbour in conditions of zero visibility. To demonstrate this he arranged to have mounted, at right-angles to one another, two broad-beam parabolic reflectors with their respective horizontal aerials energized in opposition from a common transmitter. In this way a very sharp zone of minimum signal was created in the centre of an otherwise broad region of high signal level. The whole aerial head was then made to oscillate to and fro by about plus and minus fifteen degrees so that the sharp minimum scanned a sector of thirty degrees.

In addition, the transmitter emitted two tones alternately, the change over from one tone to the other taking place when the aerial minimum was directed exactly along the desired navigation course.

On board the 'Elettra' a four-valve receiver, which had been used so successfully in all previous experiments, was modified by incorporating two tone separators corresponding to the two modulation tones applied to the transmitter. The outputs from their respective detectors were then applied to a centre-zero-indicating instrument. By this arrangement, the pointer of the indicator was deflected left and right (port and starboard) according to the tone being received at that moment.

When the 'beacon' head was scanning correctly left and right about the desired approach course, the indicating instrument would be deflected equally, also left and right, provided that the ship was correctly positioned on the approach course. Should the ship deviate from the predetermined course, an unequal deflection to left or right would be noted on the indicator. All that was necessary to keep the ship on the desired approach course was to ensure, by altering course if necessary, that equi-deflection was maintained on the indicator.

The early tests proved to be so successful that Marconi, in a very confident mood, planned a very elaborate demonstration, and invited on board the 'Elettra' representatives from all the big British shipping lines and from Trinity House.

For the demonstration, the navigation beacon was installed on the promontory at Sestri Levante at a height of 90 m above sea level. Two buoys were then anchored 90 m apart at a distance of 800 m from the shore to simulate a harbour entrance.

On July 30th the 'Elettra' steamed out to sea from her anchorage at Santa Margherita with Marconi's guests on board. With all the blinds of the wheel-house drawn so that it was impossible for the navigator to see, the yacht was successfully steered between the two buoys solely by means of the indication given by the beacon. The manœuvre required little skill and many of the guests took turns to do it themselves (fig. 10).

10 ***Artist's impression of the 'Elettra' during blind navigation trials – wheel-house blinds shown un-drawn (Painting by Chris French)***

The success of the demonstration caused great excitement amongst the guests – but more was yet to follow. Marconi had also arranged for two similar buoys to be anchored at the entrance to the harbour at Santa Margherita. By turning the receiver to face astern, and by reversing the connections to the indicator, Marconi then proceeded to carry out the same manœuvre, again most successfully, but this time at a distance of 16 km from the beacon! This, one must remember, happened over forty years ago! One is tempted to ask, with the sophisticated apparatus now available, could we do much better today?

Fig. 11 shows the next generation of satellite navigationequipment being jointly designed and built by Matra Marconi Space (UK) and GE Astro-Space (USA).

Postscript

Looking back over the years one is left with the thought, notwithstanding the painstaking experimental work that Marconi performed in the closing years of his life, his findings in the period 1932 until his death in 1937, for the greater part, fell on deaf ears. The world at large was not ready to follow his lead. It was to be two decades, in some instances, before physicists and communication engineers continued from where Marconi left off!

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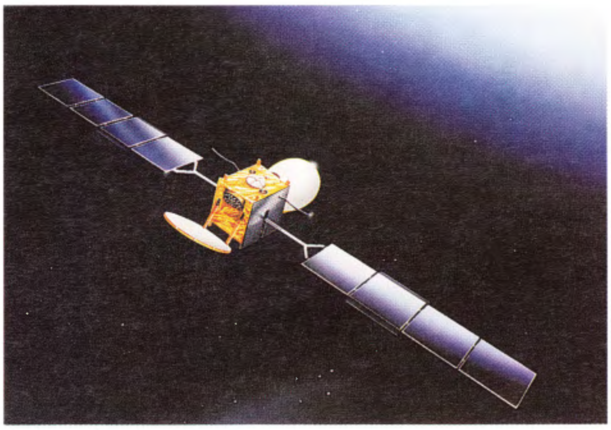
Reference (4) is included by courtesy of The Royal Institution.



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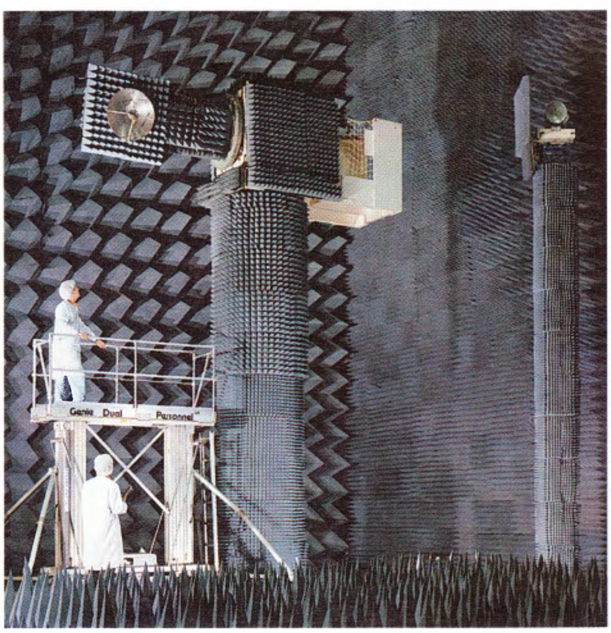

b)

11 a) ***Artist's impression of Inmarsat-3. This series of satellites is being designed and built by GE Astro-Space of the United States and Matra Marconi Space (UK). The first satellite is scheduled for delivery in 1994.*** b) ***The Inmarsat-3 navigation antenna under test on the antenna test range at Matra Marconi Space (UK), Portsmouth. (courtesy Matra Marconi Space)***

References

1 RATCLIFF, J.A., 'Marconi – reactions to his transatlantic radio experiment', *Electronics and Power*, p. 320–322, 2nd May 1974.

2 McCLAREN, J., 'Wireless Telegraphy', Inst. Marine Engineers, Dec. 1911.

3 MARCONI, G., Paper read to the AIEEE on 20th June 1922, published in *Proc. IERE*, **10**, 4, New York, Augist 1922.

4 MARCONI, G., 'Radio communication by means of very short electric waves', Discourse at the Royal Institution on 2nd December 1932, published in *Proc. Roy. Inst.*, **XXVII**, 130, p. 509–544, 1931–33.

Bibliography

BAKER, W.J., 'A History of the Marconi Company', Methuen and Co., London, 1970.

BENEDETTO, G., 'Bibliografia Marconiana'.

BLAKE, G.G., 'History of Radio Telegraphy and Telephony', Chapman and Hall, London, 1928.

BURROWS, A.R., 'The Story of Broadcasting', Cassell and Co., London, 1924.

CLAYTON, H., 'Atlantic Bridgehead'.

COLLINS, A.F., 'Wireless Telegraphy', McGraw Publishing Co., New York, 1905.

DAM, H.J.W., 'The New Telegraph', *Strand Magazine*, March 1897.

DUNLAP, O., 'Communication in Space'.

ERSKINE-MURRAY, J., 'Wireless Telegraphy'.

FAHIE, J.J., 'History of Wireless Telegraphy 1838–1899', Wm. Blackwood and Son, Edinburgh, 1900.

FLEMING, J.A., 'Principles of Electric Wave Telegraphy and Telephony', Longmans Green and Co., London, 1910.

FLEMING, J.A., 'Guglielmo Marconi', *J. Roy. Soc. of Arts*, November, 1937.

GODWIN, G., 'Marconi – a War Record, 1939–1945', Chatto and Windus, London, 1946.

ISTED, G.A., 'Guglielmo Marconi and communication beyond the horizon', *Proc. IEE*, 1958.

JOLLY, W.P., 'Marconi – a Biography', Constable, London, 1972.

MALMGREN, E., 'Christmas Greetings 1901', TELE NR4.

MARCONI, D., 'My Father Marconi', Frederick Müller, London,1962.

READE, L., 'Marconi and the Discovery of Wireless', Faber, London, 1963.

SOLARI, L., 'Storia della Radio', S.A. Fratelli Treves Editoria, Milan, 1939.

EASTWOOD, SIR ERIC, JOLLY, W.P., ISTED, G.A., RATCLIFFE, J.A. and GARRETT, G., 'Marconi Centenary', *Electronics and Power*, J. Inst. Electrical Engineers, May 2nd., 1974.