CQD • MGY

Wi-Fi is all the rage and "wireless", a term that lay dormant for decades, has re-entered common use. But linking up computers using wireless is a rather different application to that conceived by its developer, Guglielmo Marconi.

Ian Petticrew looks back to the early days of wireless and to the event that, more than any other, brought it to public attention.

"*No man will be a sailor who has contrivance enough to get himself into jail; for being in a ship is being in a jail, with the chance of being drowned.*" Doctor Johnson's sagacious observation flashed through my mind as I watched the panic-stricken steerage passengers portrayed in the 20th Century Fox blockbuster, "Titanic", locked below decks as the great liner slowly sank.

I trained for a career in the British Merchant Navy. Considering the demise that once great fleet was to suffer, it was perhaps fortunate that things didn't run quite according to plan. Nevertheless, I have retained an interest in matters nautical, so on coming in from a spot of gardening to find the family engrossed in James Cameron's epic, I naturally shed the muddy boots, and with a reviving whisky and soda in hand sat down to compare Hollywood's analysis of events with those of my former mentors.

Despite the unfortunate myths that the movie perpetuates, Cameron's direction and Horner's score between them do an excellent job imparting the sense of awesome catastrophe that must have befallen Titanic's passengers and crew in the early hours of the 15th April, 1912. Although the tragic tale is well recorded, it's worth recounting the salient details.

Built for the White Star line's North Atlantic service, at 46,328 tons and 882 feet overall length, Titanic was at the time the world's largest ocean liner. On 10th April 1912, she set out from Southampton on her maiden voyage to New York with 2,300 on board. Four days later, in disregard of ice warnings, the great liner was steaming at a reckless pace for the prevailing conditions and with an inadequately equipped lookout. Shortly before midnight an iceberg was sighted a short distance ahead. Despite the watch officer promptly ordering the helm hard over and the engines to be reversed, Titanic struck the berg a glancing blow sustaining grievous underwater damage to her for'ard end. Her pumps and watertight compartments proved incapable of holding the sea at bay, and almost three hours later she went down, claiming some 1,500 lives.

By good fortune the sea was calm and those who succeeded in getting away in the liner's woefully inadequate complement of lifeboats – mainly women and children – were rescued by the Cunard liner Carpathia who arrived on the scene not long afterwards.

Two inquiries – one American, one British – failed to attribute blame were it rightly lay; there were reputations to protect, not least of which was that of British shipping.

> "Until the dawn of this century ships great and small sailed for distant ports and, once they had passed over the horizon, were lost to the world until weeks or months later when they were again sighted on shore. Once out of sight of land those who went down to the sea in ships belonged to another world – a world of stark loneliness and utter silence. Ships burned or foundered in storms with not so much as a whisper reaching land to tell their fate. The crew of a sinking or burning ship fought their battle for life, silently and alone. Wireless telegraphy with its magic powers was to wrest from the sea its ancient terror of silence and to give speech to ships which had been mute since the dawn of navigation."
>
> ***Karl Baarslag, "SOS to the Rescue", 1935***

For me, one fact stands out. But for wireless, then in its infancy, all the hapless participants in this disaster might easily have perished in the North Atlantic's freezing wastes in circumstances that would remain a mystery. Indeed, the drama surrounding Titanic's distress calls, telegraphed on her primitive spark transmitter; of Carpathia's frantic dash through the ice fields in response; and of the Californian lying stationary nearby, her watch officers oblivious to the true nature of the events they were witnessing, must surely account for much of the continuing fascination and controversy surrounding this among all maritime tragedies.

Wireless and the spark transmitter

Everyone has heard the crackle caused by switching a light on or off near to a radio. A spark, caused by unquenched switch contacts, propagates electromagnetic radiation that the radio detects. With the addition of a modicum of tuning and an aerial (fig. 1 overleaf), the "spark transmitter" (fig. 2 overleaf) exploits this phenomenon.

The German physicist, Heinrich Hertz, first demonstrated the existence of radio waves in 1888. He charged up a capacitor linked to a pair of metal rods placed end to end, but separated by a small air gap. When the rods received sufficiently high opposing charges to cause a spark to jump the air gap, the resulting current oscillated back and forth generating radio waves that he was able to detect over a short distance using similar circuitry.

Guglielmo Marconi, then in his teens, read an account of the experiment. Unlike Hertz, who regarded the phenomenon as a scientific curiosity, Marconi saw the spark transmitter's commercial potential. Using his family's considerable wealth and substantial business contacts, plus his undeniable talent for scientific investigation and improvisation, Marconi set about exploiting communication without wires ("wireless") commercially, mainly to provide something never before possible, a means of communicating with ships beyond the horizon. In 1900, Marconi formed the Marconi International Marine Communication Company to install and operate services between ships and land stations. Twelve years later his company would become inextricably linked with the Titanic.

As for Hertz, he died in 1894 at the age of 36, before wireless had come of age, but his name lives on in the unit of frequency (i.e. waves per second) as hertz (Hz), kilohertz (KHz), megahertz (MHz), etc.

The diode and the triode

Radio's next significant development came in 1904 with the invention of the "thermionic valve" (fig. 3 on page 46), so called because when heated, the input electrode (cathode) gives off electrons that can be attracted to a positively charged output electrode (anode). In this condition, current flows from cathode to anode, *but not in the reverse direction*. This important property enabled the "diode" to address a difficult problem, that of "detection".

Radio waves captured by an aerial need to be converted from alternating to direct current in order to drive an electromechanical output device, such as a printer, headphones, or speaker. Detection had been carried out using crude electromagnetic devices that were neither particularly sensitive nor reliable. The diode offered a much-improved electronic solution.

The two-electrode diode was followed in 1906 by the three-electrode "triode", which would eventually lead to major strides in the development of radio and, later, digital computing. The triode was in effect a diode with the addition of a fine mesh or "grid" between cathode and anode to provide a means of controlling the current flowing through the valve. In principle, the grid performs the same function as a mechanical valve used to control a high-pressure flow of water through a pipe; tightening the valve restricts or stops the flow of water while loosening it has the opposite effect. In the same way, extremely faint radio waves picked up by an aerial, when fed to a triode's

Figure 1: The aerial, resonance and tuning

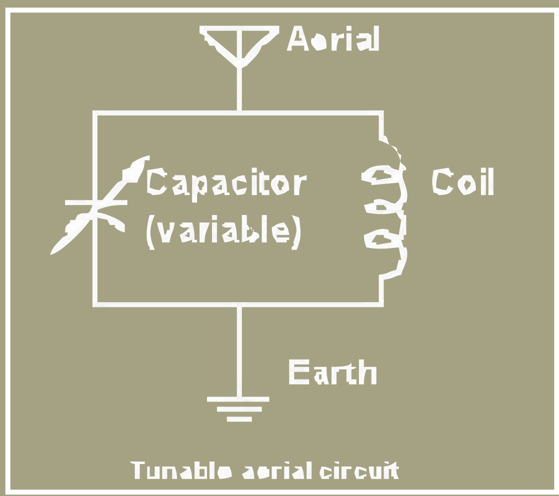
All wireless – whether transmitting or receiving – requires some sort of aerial (or antenna), which is an arrangement of electrical conductors optimised for wireless use. When acting as a transmitter, a wireless frequency alternating current (in Titanic's case, from a spark gap oscillator) is applied to the aerial causing it to radiate an electromagnetic field. Conversely, when placed into an electromagnetic field, the reverse applies, and the aerial produces a wireless frequency alternating current in response. In both cases the aerial's performance is optimised to a particular frequency using a property that physicists call "resonance".

All systems have certain normal modes of vibration. Applying a periodic force will cause a system to vibrate or "oscillate" with a frequency proportional to the force. This type of vibration is known as forced oscillation. Normally forced oscillation is of small amplitude, but this grows very quickly as the system approaches its "resonant frequency". At resonance, the amplitude of oscillations would in theory approach infinity were they not limited by friction in mechanical, and by resistance in electrical, systems.

In an electrical circuit, resonance occurs at the frequency at which the circuit's inductive and capacitive components are of equal magnitude. This causes electrical energy to oscillate between the magnetic field of the inductor and the electric field of the capacitor. In a wireless receiver, this property is exploited in the aerial circuitry by tuning it to resonate at the broadcast frequency of the selected transmitter, thus separating the required signal from thousands of other unwanted signals. This is can be achieved by varying the tuning circuit's capacitance or inductance.

Aerials come in all shapes and sizes depending on the frequency range in which they are to work. They range from long wires at the low frequency end of the spectrum, through whip aerials to satellite dishes for handling very high frequencies.

Titanic used long wires, being fitted with a "T" type aerial comprising four vertical risers, connected at one end to the transmitter room and at the other to four horizontal wires (held apart by spreaders at each end) strung between the ship's two masts, some 200 feet above sea level.



grid, can control a strong current passing through the valve. The "amplified" output signal - a facsimile of the weak aerial signal fed to the grid - can then be channelled to the detector, thereby making intelligible much weaker signals than had previously been possible. Likewise, a further triode can be used to amplify the detector's output to provide an audio signal capable of driving speakers rather than headphones (fig. 4 on page 46).

Of equal significance to power amplification was the discovery that by feeding back part of a triode's output signal into its grid, a technique called "positive feedback", the circuit became self-regenerating. In other words, the triode became a "radio frequency oscillator" (i.e. a generator of radio frequency waves)[1].

Hertzian spark gap oscillators of the type used in marine wireless of the Titanic era were notorious for their dirty, broadband radio frequency outputs. Like the emanations from a badly suppressed electric drill, they were rich in harmonics that wiped out large areas of the radio spectrum. The triode was to supersede the spark gap oscillator and dispense with the heavy iron-cored induction coils needed for powerful spark generation, thus making radio transmitters far more portable. Furthermore, unlike the spark gap, the triode could generate continuous clean waves at a single frequency, thus permitting communications over a single narrow channel. As we shall see, had these applications of the triode valve been exploited in the marine wireless of the time, the role of the Californian in the Titanic disaster might have been different. Alas, the means to produce a good vacuum on a commercial scale were not available in 1912, resulting in the thermionic valves of the time being short-lived, unreliable, expensive to manufacture and little used.

1 Hold a microphone near to an audio speaker and a deafening whistle will result. Such audio oscillations are caused by the microphone detecting noise from the speakers, feeding it back into the amplifier causing the noise to increase still further, and so on – this is "positive feedback".

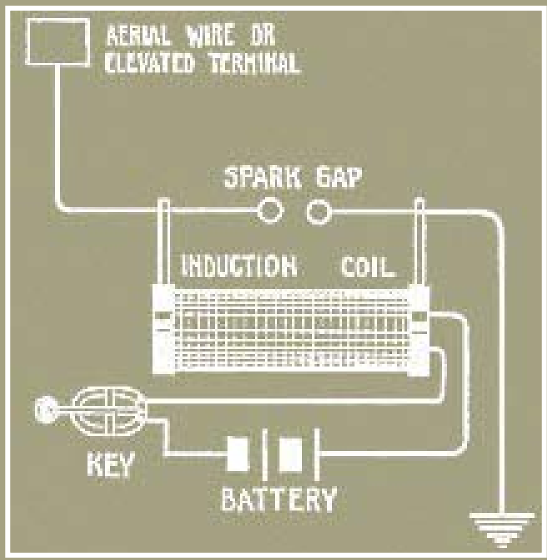
Figure 2: The Spark Gap Transmitter

The simplest wireless transmitter consists of a power supply and a wireless frequency oscillator. Before the valve oscillator, wireless frequency waves were generated using a “spark gap”. The Rhumkorff coil, used by Marconi, combined the necessary circuitry – primary coil, spark coil, interrupter, and spark gap – into a single unit.

In a Rhumkorff coil, the interrupter’s contacts were wired in series with the battery and primary coil. Closing the Morse key applied power to the primary coil and the resulting magnetic field pulled the interrupter contacts apart, breaking the circuit and causing the magnetic field to collapse. The collapsing field released the contacts, which then closed, causing the entire cycle to repeat. In effect, the Morse key operated a giant electric buzzer.

The interrupter’s rapidly opening and closing contacts caused an equally rapid rising and falling magnetic field in the primary coil. Acting as a step-up transformer, the primary induced a sufficiently high voltage in the induction coil (i.e. the secondary coil) to cause arcing across the spark gap, which in turn generated a wireless frequency alternating current in the aerial circuit. The operator controlled the transmitter’s output by turning it on and off (in Morse code) using a special telegraph key fitted with large contacts to carry the heavy current.

Although spark transmitters were simple, they blotted out large areas of the radio frequency spectrum. They also gave rise to technical problems due to the very large induced voltages when the spark struck, causing insulation break down; to high temperatures and hence to cooling difficulties; and to wear on the electrodes. All would be a nightmare for today’s health and safety inspectors! Unsurprisingly, their use is now prohibited in many countries



Modern warfare is noted for its technical spin-offs. Shortly before the outbreak of WW1, the French acquired a practicable means for producing an excellent vacuum and their military scientists quickly employed the technique to produce a reliable and efficient triode valve for use in military communications. Only when the war ended did large numbers of cheap and reliable valves appear on the surplus market, thus making possible the development of highly selective and sensitive radio transmitters and receivers. By the 1920’s, engineers had learned to modulate the amplitude of wireless waves, thereby allowing the transmission, not only of the on/off Morse code used in wireless telegraphy, but of voice and music. And so entered the golden age of radio broadcasting.

Keep out! Shut up, shut up! I am busy

Although primitive by modern standards, Titanic’s wireless equipment was the best then available. Built by the Marconi Company, her spark transmitter guaranteed a range of 250 miles under any weather conditions but could usually maintain communications over at least 400 miles. It was operated and maintained by two Marconi Company operators[2] assigned to Titanic for the voyage, their primary task being to handle the lucrative telegram traffic generated by the many wealthy and highly influential passengers on board.

2 “Spark gap” transmitters are the reason why wireless operators came to be nicknamed “sparks”.

Figure 3: the diode and the triode

The electrodes are enclosed in evacuated glass tubes, hence in some countries what the Brits call "valves", or "thermionic valves", are referred to as "vacuum tubes".

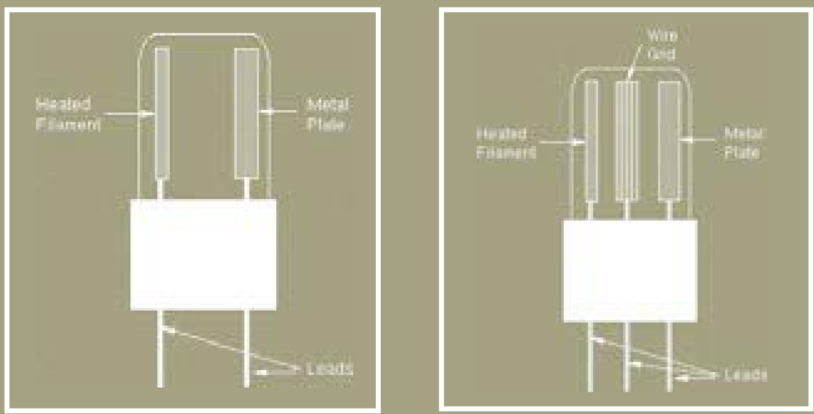
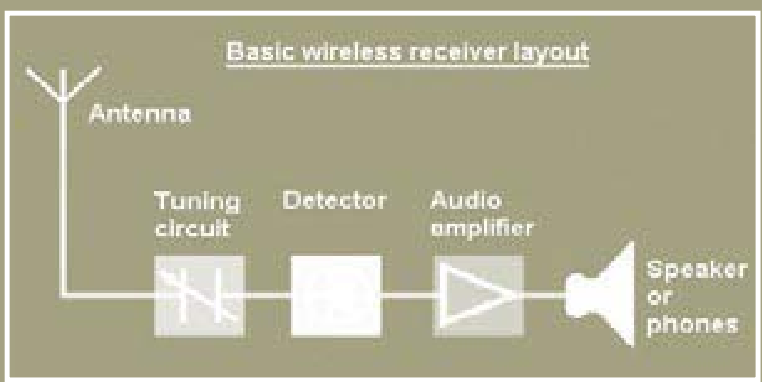


Figure 4: the wireless receiver

The basic wireless receiver can be separated into five components:

- The aerial increases the surface area of conducting material available to the transmitter's electromagnetic waves to interact with.
- The tuner separates the required signal from the thousands that interact with the aerial.
- The tuner's output is then passed to the "detector", where the alternating current signal is converted to direct current suitable for operating the speaker of headphones.
- The detector's output is then amplified in strength before being passed to a speaker or headphones.
- The speaker or headphones convert the amplified direct current signal into audible mechanical energy.

In 1912, valve amplifiers were uncommon outside of the telephone business where they were used to amplify traffic on long-distance circuits, and would not have been used in the crude wireless equipment of the ships that communicated with Titanic. Indeed, it is on record that Titanic's two Marconi operators struggled to hear the barely perceptible unamplified signals from other ships over the fierce roar of escaping steam from her boilers (released to prevent explosions as the cold sea water rose around them).



21:00 (approx), 14 April 1912. Californian to Titanic: "Say, old man, we are stopped and surrounded by ice".

21:10 (approx), 14 April 1912. Titanic to Californian: "Keep out! Shut up, shut up! I am busy, I am working Cape Race".

21:15 (approx), 14 April 1912. Titanic to Cape Race, Newfoundland: "Sorry, please repeat. Jammed".

Prior to the iceberg collision, Titanic had received several wireless messages warning of ice ahead. They were not acted on. Among them was a message from the Californian, which was in Titanic's vicinity. Her sole Marconi operator had been transmitting ice warnings since the previous afternoon, and that evening had tried to warn Titanic that the Californian was stopped, surrounded by ice. But Titanic's duty operator had told the Californian to "keep out" as he was exchanging passenger traffic with the Marconi station at Cape Race, Newfoundland. Californian's transmission was "jamming" Titanic's signals.

In an age before thermionic valves were widely used in marine wireless, the spark transmitter's dirty signal, coupled with the insensitivity of the magnetic detectors and crystal receivers then in use, meant that brute force power was necessary to ensure that a signal reached its intended recipient. "Bandwidth" as a specification for transmitters and "selectivity" for receivers had yet to become established design criteria. The result was that whoever hit the air first occupied most of the spectrum, thereby denying stations within close distance the ability to communicate with others. Whatever the frequency of Titanic's and Californian's transmitters at the time of the incident, their poor bandwidth and selectivity characteristics coupled with the closeness of the two vessels – about twenty miles – allowed only one transmitter to operate[3]. Thus the blow was struck. Having been told to keep off the air and exhausted after a very long day, Californian's operator retired to bed. Shortly afterwards Titanic struck the iceberg.

Wireless to the rescue

An inspection quickly revealed the gravity of the collision damage, and the first all stations distress call was transmitted in Morse code – "*CQD MGY. Position 41.46N 50.14W require assistance struck iceberg*" – CQD being a general call (CQ) indicating that the transmitting vessel is in distress (D) and needs help, and MGY being Titanic's call sign. Although still used in 1912, CQD had been superseded by the well-known SOS, chosen specifically to be easily and instantly recognisable in Morse code (*dit dit dit, dah dah dah, dit dit dit*). That Titanic could broadcast anything was fortunate, for the previous night vibration had rubbed the insulation off a high-tension lead causing it to earth. The fault, which prevented proper spark generation and hence a transmittable signal, took six hours to repair.

Shortly after midnight the crew uncovered Titanic's lifeboats. Although there were sufficient to accommodate only half those on board, the 'women and children only' criteria coupled with the belief of many that Titanic would not sink, further diminished the number that actually got away. At 02:05 the last lifeboat cast off, leaving some 1,500 aboard the stricken vessel. Titanic's two operators remained at their post transmitting distress messages to a growing community of helpless listeners, their last faint signal being picked up just before Titanic sank.

A number of ships heard Titanic's distress calls, but none was nearby. Several – including the Russian Birma (70 miles away), the German Frankfort (140 miles away) and Titanic's sister ship Olympic (500 miles away) – altered course towards her. To the southeast was the eastbound Carpathia. Before retiring to bed, her wireless operator signalled Titanic to advise that the Marconi station at Cape Cod was attempting to make contact. To his horror he received the reply: "*Come at once. We have struck a berg.*"

A quick comparison of positions showed the two ships to be 58 miles apart. The Carpathia's master immediately ordered the helmsman to steer "North 52 West", and she set off on her historic dash through the same ice strewn seas that had spelled Titanic's fate. The crew were roused, and off duty stokers rushed to augment those already stripped to the waist in the hellish conditions of the stoke hold, shovelling ton upon ton of coal into the insatiable furnaces. On-board heating was shut down to conserve steam, and under forced draft Carpathia's speed was driven well beyond its normal limit.

The first of Titanic's lifeboats was sighted at 03:35. As dawn broke others appeared and their occupants were taken aboard. Titanic's first wireless operator was among the many who perished from hypothermia, but his deputy was found, piled with others on a collapsible raft. Suffering from frostbitten feet he was carried to the wireless room where, after 24 hours on duty, Carpathia's operator was reeling with fatigue. Together, they began transmitting the names of the 705 survivors.

Carpathia, joined by the Californian, continued to search the area. After three hours, convinced that none remained alive in the sea of ice, a course was set for New York where the survivors were landed.

00:32 15 April 1912. Carpathia to Titanic: "Putting about and heading for you".

01:30 15 April 1912. Titanic to Olympic: "We are putting passengers off in small boats." "Women and children in boats, can not last much longer".

01:37 15 April 1912. Baltic to Titanic: "We are rushing to you".

01:40 15 April 1912. Olympic to Titanic: "Am lighting up all possible boilers as fast as (we) can".

Between 02:15 and 02:25 15 April 1912, Titanic's final wireless message. Titanic to Carpathia: "SOS SOS CQD CQD Titanic. We are sinking fast. Passengers are being put into boats. Titanic."

The aftermath

The British inquiry into the Titanic disaster made a number of important recommendations covering ship construction (to reduce the risk of flooding) and speed when navigating in regions of ice, fog and other danger. The Titanic disaster also led to the "First International Conference on the Safety of Life at Sea" (**SOLAS**), held in London in 1913. It resulted in regulations requiring all passenger ships to carry sufficient lifeboats for everyone on board and for lifeboat drills to be

3 A similar problem can affect wireless LANs. Bad positioning can cause equipment to exchange signals with adjacent networks, thus giving rise to potentially serious security problems.

conducted. Although the installation of wireless equipment on ships was not made obligatory, steps were taken to improve wireless coverage, with some ships being required to maintain a permanent radio watch to avoid missing distress calls.

The "International Ice Patrol", an agency of the US Coast Guard, also came into being and to this day monitors and reports on the location of North Atlantic icebergs that threaten shipping. During the patrol season – normally from March through August – the Coast Guard broadcasts twice daily by Inmarsat satellite and by high-frequency radio facsimile, issuing reports on the locations of all known sea ice and icebergs. Some 1,000 icebergs are tracked every year.

SOLAS

SOLAS has been revised and updated many times. In 1959 it came under the auspices of the newly created United Nations International Maritime Organization (IMO - **www.imo.org**), which assumed global responsibility for shipping. Accident prevention is one of the Agency's major goals, but it also concentrates on developing global integrated systems to respond to shipping emergencies. The most significant of these are the "International Convention on Maritime Search and Rescue" (**SAR**) and the "Global Maritime Distress and Safety System" (**GMDSS**).

The GMDSS is a worldwide network of automated emergency communications for ships at sea. It means that all ocean-going passenger ships and cargo ships of 300 tons and upwards must carry radio that conforms to international standards. The basic concept is that search and rescue authorities ashore, as well as shipping in the vicinity of the ship in distress, can be alerted rapidly through satellite and terrestrial communications so that they can promptly assist in a coordinated SAR operation. However satellites offer a number of advantages over conventional radio, one of the most important being that they can avoid the problems caused by radio waves travelling in straight lines.

Because they do not follow the curvature of the Earth's surface, radio messages eventually disappear into space (except on High Frequency). Messages sent via satellite also travel in straight lines, but they can immediately be bounced back to Earth, thus greatly extending the range of communications. Instead of a ship transmitting a distress alert and hoping that another ship is near enough to hear, satellites redirect the message to a dedicated land station designed and equipped to deal with maritime emergencies.

The International Maritime Satellite Organization (Inmarsat – **www.imarsat.org**) provides shipping with a communications system reserved solely for its own use and designed for its own purposes. The Inmarsat system offers advantages that could not be provided by terrestrial radio communications. Geostationary satellites – two positioned above the Atlantic Ocean, and one each over the Indian Ocean and the Pacific Ocean – provide overlapping coverage of the whole of the Earth's surface other than the poles. The days when a ship could vanish without trace are virtually ended.

Epilogue

The Californian's master, Captain Lord, became the disaster's scapegoat, with both inquiries unjustly accusing him of failing to help a ship in distress. In 1992, thirty years after his death, a UK Government investigation vindicated him.

Although Marconi achieved his dream of seeing wireless link the world, I doubt that he could have imagined it would one day be possible to stand on the same cliff-top in Cornwall from where the first wireless message was transmitted across the Atlantic, and send a fax, e-mail or text message to anywhere in the world; or for that matter, that giant telescopes would tune in to radio waves sent from deep space. When asked by a facetious journalist whether he had ever heard signals from Mars, Marconi replied: "I am concerned enough at present with business upon Earth."