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Cornish Connections - The past, present and future of terrestrial, subsea and space communication in Cornwall.

This article is a follow on to an earlier article written in April 2018, **Mr Marconi and Mr Fisk, 100 Years of Radio** which can be downloaded here www.rttonline.com/wirelessheritage.html

In this update, we tell the story of the first long distance transmission to Newfoundland on 12 December 1901 from the Poldhu Wireless Station on the Lizard Peninsula in Cornwall to a receiver connected to a kite born 500 foot aerial at the top of Signal Hill, St John's in Newfoundland and the short and long term impact this had on the business that came to be known as Cable and Wireless bringing cables ashore at Porthcurno across the bay.[i] Goonhilly (four miles inland from Poldhu) then adds space into the mix from the 1960's.

Special thanks are due to to the outreach teams at the Marconi Museum in Poldhu, Goonhilly and The Cable and Wireless Museum in Porthcurno, now known as PK Porthcurno.

Read on

Long Wave Transmission to Australia - 1918

On September 22 1918, Marconi (1874-1937) and the Prime Minister of Australia sent a Morse code message to Ernest Fisk, head of Amalgamated Wireless Australia (AWA) using a 400 kilowatt Long Wave transmitter known as the Waunfawr transmitter located on the top of the Cefn-du Mountain in Snowdonia. The transmitter had been developed at Marconi's Chelmsford factory in 1914. The receiver was developed and built by AWA and installed at a radio station at 'Logan Brae', Pymble, an adjacent suburb to Wahroonga, near Sydney. It closely followed Marconi's proposed design using a tuning coil and variable capacitor to give a tuning range of 10 KHz to 30 KHz (30 kilometer wavelength to ten kilometer wavelength).

Long Wave Transmission to Newfoundland 1901

17 years earlier on 12 December 1901, Guglielmo Marconi and two assistants (George Kemp and Percy Paget) nursed a long wave receiver (a set of headphones probably attached to a simple coherer or magnetic detector) into life on the top of Signal Hill in St John's Newfoundland and made history by hearing three dots (the Morse code letter S) transmitted from the Poldhu Wireless Station on the West coast of the Lizard Peninsula in Cornwall sent at three pre-arranged times (12.30, 1.10 and 2.20 pm). The 13 kilowatt spark transmitter was centred on 819 KHz (366 meter wavelength) radiated from two 61 meter masts. Marconi had proved that radio waves could travel round the world. The transmitter designed by Ambrose

Fleming represented a major step forward in long distance wireless transmission and was perceived as a potential threat to the subsea cables connecting Porthcurno with the US and India and the rest of the British Empire. A regular telegram service to Nova Scotia was established in County Galway in 1906 with Poldhu reverting to providing communication to deep sea fishing vessels and a nightly Morse code news bulletin used to print daily newspapers on transatlantic liners.

Mark Raboy's comprehensive book, 'Marconi: 'The Man who Networked the World' documents how a 22 year old Marconi spotted an opportunity to translate his interest and knowledge and contacts in the fledgling radio wireless industry into a business opportunity. While never achieving a complete monopoly over early radio and broadcast communications, he achieved market dominance in maritime communication that transformed the Wireless Telegraph and Signal Company established in 1897 into one of Britain's most successful and strategically important companies (Marconi Communications and GEC Marconi). The wireless part of Cable and Wireless was also built on Marconi's legacy though Marconi never thought that this was a remotely good idea.

That aside, in many ways Marconi was a younger manifestation of John Pender. John Pender (1816-1896) and the history of the company that he founded that became Cable and Wireless, is described in detail by a number of excellent books and recorded in the history archive and museum at PK Porthcurno (see the resources section at the end of this article).

John Pender dominated a fledgling subsea cable business and can therefore be placed into context with similar (later and earlier) pioneers who achieved financial success by spotting and acting on market opportunity earlier than their competition, achieving the fiscal magic of first mover advantage. So here is a potted history of Mr Marconi, Mr Rockefeller, Mr Carnegie, Mr Vanderbilt, Mr Pender and in the interest of contemporary technology historians, Mr Musk, not forgetting that without Isambard Kingdom Brunel, all of the above might have had a harder journey to achieve national, regional and in some cases global domination.

Mr Marconi

Marconi's early seed corn financing came from his Italian family and Italian connections though it was the British government and his Irish connections via his mother (a daughter of the wealthy and influential Jameson whiskey family) that provided the most favourable investment climate. In the early years of a unified Germany's military build-up, set in train by Otto Von Bismarck, there was an emerging interest in technologies that could deliver military advantage. In parallel, there was political recognition that finding new ways of commanding and controlling and influencing a fractious British Empire were required.

Mr Rockefeller, Mr Carnegie and Mr Vanderbilt

Similar forces were at work on the other side of the Atlantic where John D. Rockefeller (oil), Andrew Carnegie (steel) and Cornelius Vanderbilt (ships) were allowed and in some cases encouraged to establish monopoly businesses that were considered to be helpful to US national security and financial stability.

John D Rockefeller (1839-1937) invested in the Cleveland Ohio refinery in 1863 and established Standard Oil in 1870 which by the early 1980's controlled 90 per cent of US refineries and pipelines. Carnegie and Vanderbilt achieved similar levels of market domination and supply chain control. All three became subject to anti-trust laws but by then had become spectacularly wealthy. This era is sometimes called the Gilded Age after the 1873 Mark Twain Novel.[ii]

Mr Pender (1816-1896) (and Mr Charles Tilston Bright 1832-1880)

Mr Pender had made his initial fortune as a cotton merchant in Manchester but in 1852 joined the board of the English and Irish Magnetic Telegraph Company running a telegraph service between London and Dublin. The first submarine cable had been laid between England and France two years earlier and a subsea cable to India was under construction. Pender then joined the board of the Atlantic Telegraph company with an ambition to connect Britain and the United States. Initial attempts were unsuccessful but by 1866 the first cable was made operational, overseen by the company's Chief Engineer Charles Tilston Bright. [iii] This remarkable achievement marked the start of 30 years of cable laying connecting Britain to Gibraltar, Malta, Bombay, Singapore, Australia, Brazil, Chile, Argentina and Africa and a cable empire that was to last for 100 years (the last telegram cable was decommissioned in Porthcurno in 1970).

Mr Cook, Mr Wheatstone Gutta Gum Trees and Mr Brunel

John Pender died in 1896, a wealthy man, but none of the above would have been possible without William Cook and Charles Wheatstone's invention of the telegraph (in 1837, partially sponsored by Brunel), the sourcing of sap from the Malaysian Palaquium Gutta tree and Mr Brunel's 700 foot long ship, the SS Great Eastern.

Gutta Percha gum was first imported into Britain in 1843. Initially used to make decorative items such as chessmen, it proved to be an excellent insulator initially for terrestrial telegraph systems and then for subsea cable. Usefully for subsea cables, the insulating properties improved under pressure and at at low subsea temperatures. Gutta Percha was used well into the 1930's when it started to be replaced by polythene. The Gutta Percha Company set up in 1845 by John and Jacob Brett laid the Dover to Calais cable in 1851 and dominated cable manufacturing and cable manufacture and deployment through the 1850's. By 1861, they were

importing 1000 tons of Gutta Percha per year and by 1865 the company had supplied 14,000 miles of cable core for 64 cables. [iv]

To build the 1865 Atlantic cable, The Gutta Percha Company merged with one of their major customers, the cable manufacturer Glass Elliot and Company to form the Telegraph Construction and Maintenance Company (Telcon) integrating cable manufacturing with cable laying. Conveniently Mr Brunel's ship was for sale. Originally designed to take 4000 passengers to Australia on one load of coal, the SS Great Eastern had been a financial failure mainly because 4000 people didn't want or need to go to Australia but being so much longer than any ship built at that time, it was ideal for cable laying. The SS Great Eastern laid down the first 2600 miles of transatlantic telegraph cable in 1865. By the time the ship was decommissioned in 1888 it had laid a total of 30,000 miles of cable.[v]

The first transatlantic cable in 1856 had seven conducting wires wrapped in three coats of Gutta Percha wrapped in tarred hemp (Mr Wheatstone's idea) then an 18 strand sheath of iron wires.[vi] By 1866, these cables were transmitting across the Atlantic at six to eight words per minute at $5 dollars per word at 1866 dollar value. Even at a deployed cost of $1 Million dollars, these cables provided a good return. By 1900, there were ten Atlantic Cables with ten more under construction with 36 ships laying new lines and repairing 130,000 miles of legacy cable.

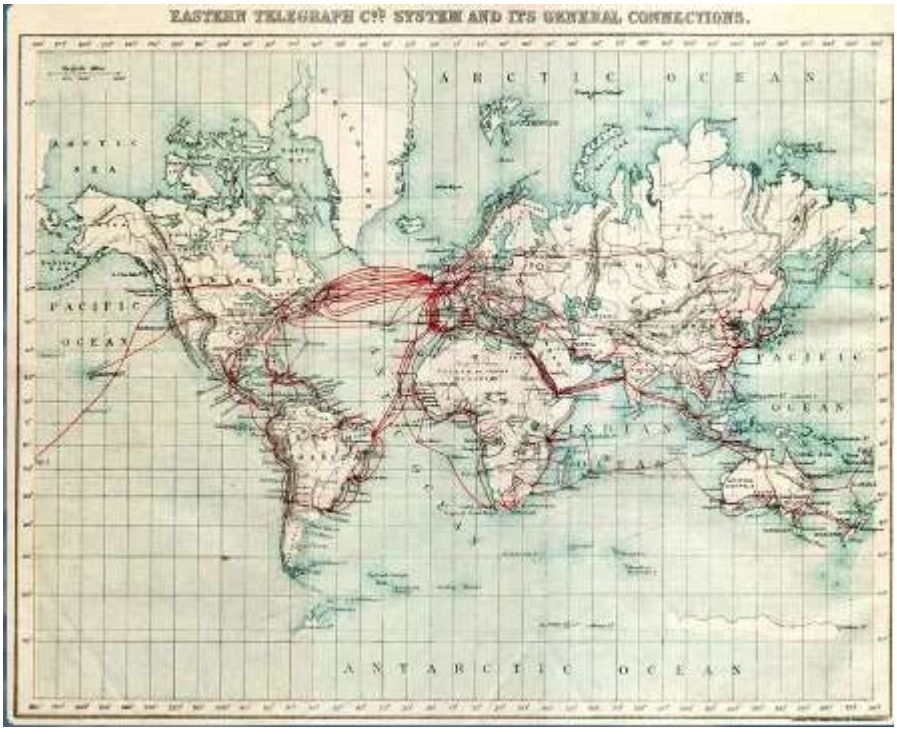

Figure 1 Global Cable Map 1898 Image Credit PK Porthcurno

By 1928, transatlantic speeds had increased to 400 words per minute but long distance voice remained problematic and it wasn't until the 1950's that amplifiers spliced into the cable paid out from a cable ship became reliable enough to justify the cost of using them every 20 miles along a 2000 mile cable. In 1956, a duplex telephone cable known as TAT-1, (actually two cables Eastwards and Westwards) was deployed carrying 36 channels each of which was equivalent to 22 telegraph circuits. Calls cost $3dollars a minute equivalent to about $20 dollars per minute today. By 1966, TAT-6 had been deployed supporting 4000 telephone channels.

Fiber under the sea

In 1988, TAT-8, the first transatlantic fiber optic subsea cable was laid supporting 40,000 channels. Fiber subsea cables still have a conductor (glass not copper), an insulator (polyurethane rather than Gutta Percha) and a strength member (steel instead of iron)but have a substantially tighter bending radius and can be deployed from relatively small ships (450 feet rather than the Great Eastern' s 700 feet) at a laying rate of 150 kilometers per day.

Figure 2 shows an 1858 subsea cable next to a 2008 fiber cable.

Figure 2 Submarine Cable Comparison Image Credit www.submarinecablesystems.com/history

Single and Multi- Mode Terrestrial and Subsea Fiber

Today most, but not all, long distance (terrestrial and subsea) fiber is single mode. In single mode fiber, the light wave propagates parallel to the axis of the fiber. This means there is no modal dispersion (more about this in a bit) with reach limited by polarisation loss and chromatic dispersion. The big leap forward in fiber capacity has been the shift from on off keying (OOK) via two or four level intensity modulation to coherent modulation in which information is phase modulated on to the optical carrier. This transition has been enabled by the ever improving performance of digital signal processors at either end of the cable and is similar to the gain achieved in copper cables using ADSL or VDSL. The default frequency is

Optical C band (191-195 THz) though super C band is now being deployed adding an additional 3.5 THz of pass band. Channel spacing can either be 100, 50 or 25 GHz. A few fibers packed together means that the cable is easy to handle, the outer cable remains flexible and the bending radius remains relatively tight. More fibers mean less flexible cabling and a more complex termination process.

Single mode and multi- mode fiber both work on the principle of total internal reflection. A core of doped glass is surrounded by an outer core of clear glass with the clear glass having a higher refractive index than the core. In multi-mode fiber, multiple beams of light at the same wavelength but with different angles of reflection are reflected back from the boundaries of the core which means that the beams have different path lengths and thus are separated in time and can be demodulated as separate light paths. **(Figure 3)**

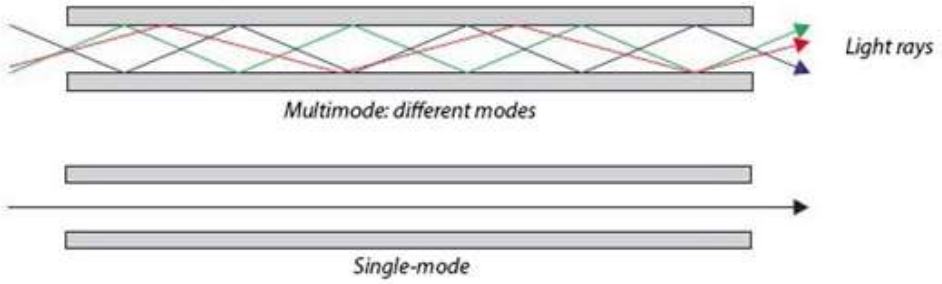

Figure 3 Single Mode and Multi-Mode Fibre-Reprinted from 5G and Satellite RF and Optical Integration Chapter 2

As with single mode fiber, individual multi-mode fiber can be bundled together into an outer cable. Up to 6912 cables can be packed into an outer diameter of 1.14 inches though the cables need to be ribbon spliced which introduces losses. Optimised single mode fiber can have losses below 0.2dB/km. In 1970, typical cable loss was 20dB/km which goes a long way toward explaining why and how fiber has become increasingly cost effective over time.

This is frustrating for people that remember Cable and Wireless and Porthcurno in particular in its heyday. If we take 1870 as the start point (Porthcurno as the world's first landing station for the British to Bombay Cable) and then nip in to our time machine to move on 150 years we find a world interconnected by 1.3 million kilometers of subsea cable (800,000 miles). None of these are owned by Cable and Wireless as it no longer exists as an independent company. Instead they are owned by companies that did not exist fifty years ago (Microsoft) or thirty years ago (Google, Amazon, Facebook, Apple, Tik Tok, Ten Cent and Baidou).

In February 2021, Google and its engineering sub-contractor SUBCOM commissioned the Dunant subsea cable connecting Virginia Beach in the United States to St Hilair de Riez on the French Atlantic Coast. Named after the founder of the Red Cross, the 6600 kilometer cable

carries 12 fiber pairs and is claimed to be the first long-distance cable to use space division multiplexing (SDM), effectively multi-mode fiber.

Each fiber pair supports a data rate of 25 Tbps yielding a cable capacity of 250 Tbps. The use of SDM means that pump lasers and related photonic and optical components can be shared across all fiber pairs opening up the opportunity to realize higher pair counts; up to 24 pairs being regarded as practical in the near future. As of today, 16 fiber pairs can carry 180 Tbps over subsea paths of thousands of kilometers with visibility to 500 Tbps in the near future.

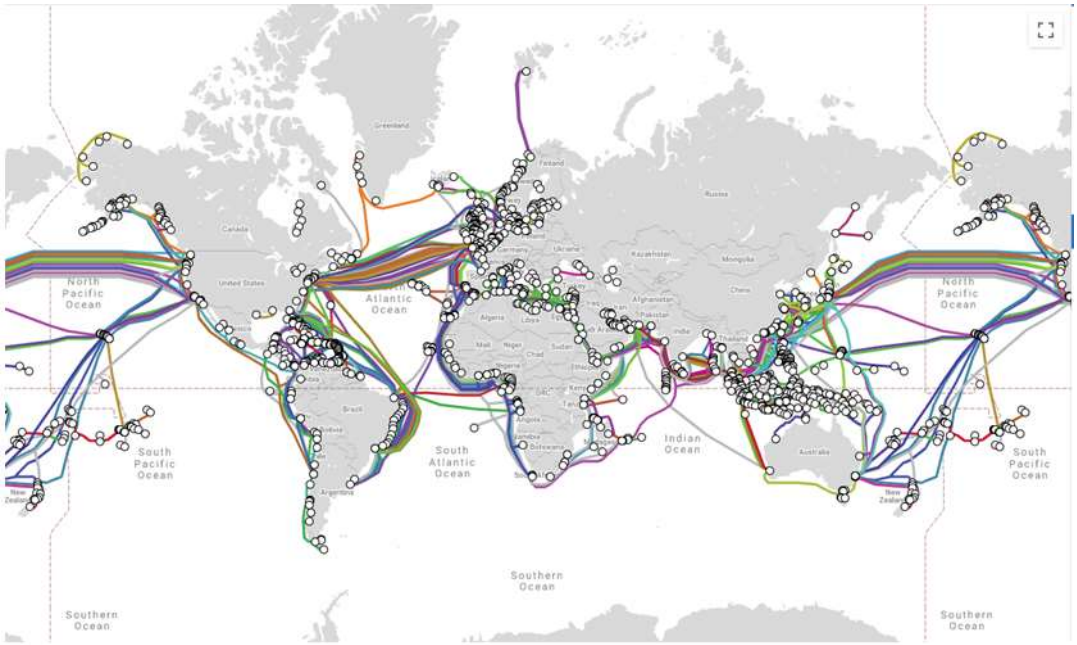

Figure 4 Major fiber routes in 2024 Image Credit Telegeography

So how did Cable and Wireless miss out on this technology driven renaissance of the subsea cable business? The ninety year timeline summarizes the story and the sad ending.

The Potted History from Fame and Fortune to Failure

1928: the formation of Cable and Wireless following a merger of the Eastern Telegraph Company with the Marconi Wireless Telegraph & Signal Company. (Marconi opposed the merger but had lost the chairmanship of the company the year before).

1947: Post war nationalization.

1969: The first standards emerge for what later became the Internet.

1981: Privatization under Margaret Thatcher and the setting up of Mercury Communications to compete with BT (a politically driven rather than commercially driven decision).

1987: The handover of Hong Kong to China (for many years Hong Kong had been the main source of profit for Cable and Wireless).

1989: The first standards emerge for the World Wide Web.

2000: The NASDAQ index peaks at 5048 on March 10, 2000. By October 2002, the index had lost 76.81%, of its value. Many dot com stocks go into Chapter 11 joining Iridium, Globalstar and Teledesic (the first generation of LEO radio networks).

2002: The world's first camera phone, the Nokia N650.

2007: The first generation Apple iPhone.

2009: The decision to set up two separate businesses, Cable and Wireless Communications and Cable and Wireless Worldwide

2009: Nortel files for bankruptcy

2012: The sale of Cable and Wireless Worldwide to Vodafone for $1 billion

2015: The sale of the rest of the business to Liberty Global for £3.5bn plus £1.8bn of debt.

Over this same period, thanks to a combination of the internet, the World Wide Web and smart phones, Microsoft and Apple and Google built businesses worth trillions of dollars employing (directly or indirectly) millions of people. The factories (now in China) producing the iPhone employ over one million people. Cable and Wireless at its peak employed 54,000 people around the world and in 2000 had an enterprise value of $38 billion. In 2023 Liberty Global made a loss of $3.9 billion and had debt of $15.9 billion.

Debts and a developing disaster

The problem that Cable and Wireless had is similar to other UK utilities including most recently the water industry. Utilities are attractive to private investors because they are considered to have captive customers yielding stable revenue and high margins.

However this also makes the companies easy to load with debt and this makes them sensitive to price erosion or loss of revenue from new competition particularly competitors with large amounts of cash on their balance sheet. As this new competition begins to bite, hedge funds start shorting the stock and the debt load becomes harder to service. For Cable and Wireless, privatization came hand in hand with market liberalization. This eradicated the margin premium achievable from market monopoly. The bursting of the dot com bubble in March 2000 and over supply of fiber bandwidth made things even harder. A move into data centre hosting was a good idea but badly timed (see above). In common with GEC Marconi, it could be argued

that the decision (to buy into a US supply chain) and a new market (the provision of internet services) was the right decision at the wrong time.

New Competition- Space Communication as the next big thing?

Even if Cable and Wireless had survived, it would now be facing new competition from across Porthcurno Bay, not from Marconi but from the Goonhilly Satellite Earth station four miles inland from Poldhu. On July 11th 1962 at 1.00 am, Goonhilly transmitted the first inter-continental picture between the USA and Great Britain. The Goonhilly dish had a diameter of 85 feet, weighed 800 imperial tons and ushered in an age in which telephone calls and television broadcasting via geostationary satellites became an every day part of our lives.

Sixty years on, Goonhilly has become the first private organisation to be qualified to provide services to NASA's Near Space and Deep Space Network using two existing though modified 30 and 32 metre antennas.[vii] Goonhilly has also purchased two teleports on the West and East Coast of America and are hosting a Starlink Ground Station.

Smart Phones and Satellites

Twenty years ago, smart phones had 2 Megapixel cameras and a few hundred kilobits of transmission bandwidth. Ten years ago smart phones had twenty megapixel cameras and megabits of transmission bandwidth. Today smart phones have 200 Megapixel cameras and are heading towards gigabits of transmission bandwidth.

A similar bandwith expansion has happened in space. The Hubble Space telescope, launched thirty years ago into a Low Earth Orbit at 525 kilometers produced (and still produces) two Gigabytes of imaging data per day. The James Webb Telescope launched in 2021 into a solar orbit 1.5 kilometers from Earth (one million miles) generates 50 gigabytes per day but to this you need to add thousands of low orbit satellites that are imaging the earth on a continuous basis producing exabytes of data.

An RF (Radio Frequency) to Optical Transition?

Starlink now has over 6000 satellites in space. The satellites have coherently modulated lasers that providing optical cross switching across nine orbital shells ranging from 340 kilometers to 614 kilometers. These links support potentially hundreds of terabits of transmission bandwith and long distance end to end routing that is faster than subsea fiber(photons travel faster in space than they do in fiber), connected to ground stations by high capacity optical links. Starlink is effectively the world's first Global Wireless Optical Network (G-WON). The provision of direct to cell phone services also means that Starlink can bypass the terrestrial cellular phone industry though Mr Musk is unlikely to be allowed to do that. However never understimate the ability of

the cable industry to respond to new competition. The Breen Leisure Park on the South West Coast is one of the termination points for the Hibernia Express cable that creates a vacuum within the cable to match the free space rates available in space (300 million meters per second rather than 270 million meters per second), reducing the London to New York latency to 59 millseconds (from 65 milliseconds), a major enabler for high freqency trading.

Mr Musk and Mr Pender

Even if he does not take over the business of 600 cellular operators and or by-pass sub sea cable, Elon Musk owns 50% of the equity of Starlink's parent company Space X giving him control of 78% of the voting rights. Space X controls 80% of the global rocket launch market (China is 10% and the Rest of the World 10%), a level of control over his companies that is similar to Mr Pender's control of subsea cable markets at the end of the 19th Century. Notoriously he also owns X (formerly known as Twitter and acquired for $45 billion) which might prove/already is proving to be a problematic investment and seems to be running America in his spare time.

Very big ships and very big rockets

But to finish on a positive note, like Isambard Kingdom Brunel, Mr Musk loves building things that are bigger than anything built before. The Super Heavy Starship is the tallest rocket ever at 120 meters (394 feet) and has been designed to scale to a launch weight of 5000 tonnes carrying a cargo of 500 tons. To put this into perspective, the International Space Station weighs 450 tons and needed 50 shuttle launches to get it 250 miles (402 kilometers) into space.

As with ships, the bigger the rocket, the more efficient it becomes technically and economically.

Cornwall as part of the Space Communications Revolution

Cornwall can be rightly proud that it is an important part of this new space communications revolution. Apart from Goonhilly there is also now a Space Port and Space Hub in Newquay.

Mr Pender returns to Porthcurno

If John Pender was to step out of his time machine onto Porthcurno Beach and make his way up to the Cable Hut at the top of the beach he might initially think that not much had changed in the last 150 years but if he was to look up into the night sky and see those twinkly objects flying hundreds of kilometers above his head, making their way from horizon to horizon every five to fifteen minutes and carrying terabits and shortly exabits of data round the world in a few tens of milliseconds he would hopefully be surprised and impressed and pleased that the long distance communications revolution that he helped to start has turned out rather well.

Figure 4 Cable Hut at the top of Porthcurno beach

Resources

Cable and Wireless Museum Porthcurno (now PK Porthcurno), A Short History of Cable and Wireless.
Changing Places: Porthcurno and the roots of modern communication
Girdle Round the Earth: the Story of Cable and Wireless, Hugh Barty-King
Voices over the Horizon: Tales from Cable and Wireless, David Souden
Voices of Change: Further Tales from Cable and Wireless, David Souden
From Steam to Glass: The Curious Story of Brazilian Communications
Marconi's Atlantic Leap: Gordon Bussey
Marconi: Marc Raboy
Signor Marconi's Magic Box: Gavin Weightman
The Victorian Internet-Tom Standage; Walker and Company, New York, 1998
Cornwall's Communications Heritage, John Moyle
5G and Satellite RF and Optical Integration: Artech House, Geoff Varrall

A comprehensive video explores the legacy of Edward Snowden and his exposure of the interception being applied to transatlantic cables, many of them terminating on Cornish beaches (and into innocent looking Cornish farm buildings and unusual looking bungalows and huts). The role of GCHQ in Bude is enlightening as is the observation of manhole covers as a guide to fiber intercept, the art of making transparent fiber transparent.

www.youtube.com/watch?v=K_nnUbX7uuQ&app=desktop

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[i] Debate is still ongoing as to whether Marconi actually heard the message from Poldhu but just convinced himself that he had. His faithful side man George Kemp also heard the three dots representing the letter S hidden in the static received through the headphones. Edison, initially a sceptic, was however convinced and the rest, as they say, is history.

[ii] https://www.goodreads.com/book/show/98906.The_Gilded_Age

[iii] www.britannica.com/biography/Charles-Tilston-Bright

[iv] https://atlantic-cable.com/Article/GuttaPercha/index.htm

[iv] www.eastlondonhistory.co.uk/isambard-kingdom-brunel-london

In 1965 Cable and wireless was contracted to provide and operate a Satellite Earth Station on Ascension Island. The Earth Station was operational from 1967 onwards using a 42 foot diameter dish.

Technical Foot Note

From the point at which subsea cables started to deploy repeaters into long distance links (in the 1950's) it has become necessary to send power down copper and now fiber subsea links. Recent deployments require more than 5 kilowatts of high voltage power to operate. This has gone hand in hand with the expansion of off shore wind farms where the principle purpose of the subsea cable is to carry power back to the nearest terrestrial termination point (the local National Grid) with data links (telemetry and telecommand) as a secondary (but still important) requirement.

Commercial Foot Note

The history of Cable and Wireless Cable has been comprehensively documented up to 1999, see Books and Resources listed above. What happened next can be regarded as no one's fault and the fate of Cable and Wireless was shared with many other British companies that prospered in the 1990's and then crashed and burnt over the next ten years (GEC Marconi being a notable example). The shareholders of both companies were however less than pleased. With the benefit of hindsight, if Cable and Wireless had remained faithful to its core business (no pun intended) of **cable laying and cable termination and cable repair** and on **the RF side, HF and tropospheric radio** and **ground station design and deployment** (tracking the Apollo programme from the Ascension Island Earth Station with the HF radio station in Bermuda supporting post launch telemetry) then it could now be in the business of providing integrated terrestrial, subsea and RF and optical space communication as a trusted delivery partner to most of the Rest Of the World.