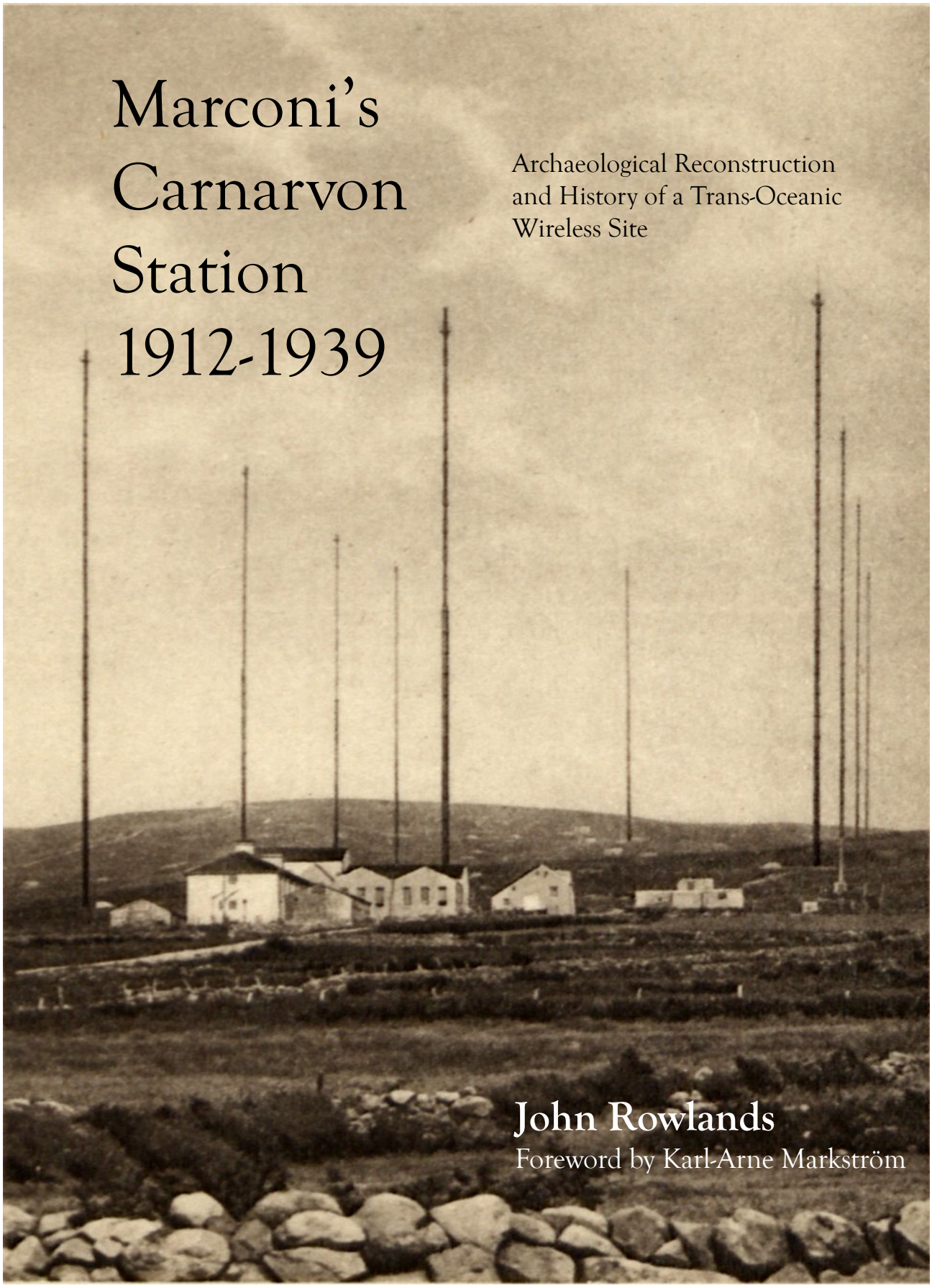
Marconi's Carnarvon Station 1912-1939

Archaeological Reconstruction and History of a Trans-Oceanic Wireless Site



John Rowlands

Foreword by Karl-Arne Markström

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A Journey Into Early Wireless in North Wales.

Front cover image: Carnarvon's first form, *ca*. 1918; Inv. 13907 © History of Science Museum, University of Oxford

Sixth Edition, 2024.

Intended extent (1913) of the Marconi Empire scheme. Bodleian Special Collections, MS.Marconi 219.

Foreword

This report, which deals with the Marconi fixed service stations MUU, GLC and GLJ at Carnarvon in Wales, depicts the zenith of long-wave point-to-point radio technology.

It has its roots in the pioneering work of early 20th century prominent engineers, inventors and entrepreneurs, with Guglielmo Marconi, Reginald Fessenden and Ernst F. W. Alexanderson standing out.

The advent of wireless telegraphy capable of world-wide coverage changed the road-map for the communications and media landscapes and made them independent from the cable companies, which was one of the primary objectives of Marconi when founding his company.

Fierce competition started between “wired” and “wireless” service providers, which peaked during the mid-1920s. Government-sponsored organisations and companies were founded for providing radiotelegraph services to even the most far-out corners of their Empires.

Stations like Carnarvon represented the peak of long-wave technologies, where massive investments in aerials, electrical machinery and ancillary equipment were required to overcome the limitations imposed by properties of the available radio spectrum. Transmitter power levels in the hundreds of kilowatts, and many miles-long aerials became needed for reliable communications to other continents.

Many inventions and developments, which later became very important for other radio applications were pioneered during this era.

The heydays of long-wave systems were however quite brief, when the short-wave spectrum started to be exploited for long-distance communications during the mid-1920s, another revolution became underway. By exploiting the newly discovered radio spectrum below 100 metres or so, international radiotelegraph circuits could be operated showing the same performance using transmitters with just a few percent of the power used by long-wave transmitters, and using at least an order of magnitude smaller aerial parks.

This, and the much expanded spectrum availability on the “short-wave bands” made the long-wave systems rapidly obsolete, relegating them to special applications such as strategic military and submarine communications in addition to radio navigation. The surviving species of the RCA/Alexanderson and Marconi wireless stations have mostly been saved by “dual-use”. In this context, the still-operational Alexanderson alternator SAQ, at Grimeton, stands out.

We can now look back on more than a century of operational and radio engineering progress, in which fundamental relations were discovered, lessons learned, dead-ends encountered and avoided, systems and techniques continually improved.

It has been a pleasure reading this work, which provides an important piece in the jig-saw puzzle of early radio systems engineering history.

Karl-Arne Markström.

Senior Systems Engineer (Ret.), Swedish Telecom Radio, owner of the SAQ site until 1997. Member, National Committee for Scientific Radio and the National Board of Radio Navigation. Radio amateur SM0AOM.

Stockholm, September 2022.

Acknowledgements.

Understanding a radio station 110 years after it was built proved to be a very considerable undertaking and, even now, is not complete. I am very grateful to the following colleagues from the amateur radio community, listed alphabetically, who kindly provided key insights, knowledge, experience and views.

Robin Davies, G7VKQ; **Jason Gardner**, G7RUX, senior radio frequency engineer; **Pascal Grandjean**, F5LEN; **Leslie Hayward**, MW0SEC, retired electrical engineer; **Graham Isherwood**, industrial archaeologist specialising in the north Wales slate industry; **Karl-Arne Markström**, SM0AOM, retired Senior Systems Engineer, Swedish Telecom Radio; **Edwin C. Moxon**, Ph.D., K1GGI, Marconi/RCA Wireless Museum, Chatham, MA, USA; **Kevin R. Porter**, G6UCY; **Michael G. Mladejovsky**, Ph.D. (electrical engineering, formerly University of Utah) WA7ARK; **Paul M. Hawkins**, career RF communications engineer and author of the 2017 book, *Point to Point: a History of International Communications During the Radio Years.*

The members of the online, *Great War Forum*, 'Home Front' section.

Dr. Fred M. Chumaceiro for his skilled preparation of the first-ever highly-detailed, accurate computer modelling of Carnarvon's radiation pattern, using state-of-the-art software.

This work was informed, and its costs reduced in equally substantial measure, by Oxford Bodleian Libraries' system of mediated copying from the Marconi archive. I am grateful to the University for this invaluable and efficient service, ably delivered by its various Special Collections staff.

Similarly, an expensive trip to London was avoided by mediated copying, kindly provided by the efficient staff of the Parliamentary Archive.

Information about the station buildings and surroundings was greatly assisted by the kind granting of consent by the present owners to access their property. Such kindness also allows the Dragon Amateur Radio Club to remind the world about the Carnarvon station every International Marconi Day via special event transmission from the site.

The vast archive of historical wireless publications created and maintained by **David Gleason** at worldradiohistory.com has been to this study, as countless others, an invaluable resource, for which the global radio community owes a considerable debt.

Key photographs of Marconi's Marion station, Massachusetts, USA, were kindly provided by **Marian Howell**, in association with the Sippican Lands Trust.

Thanks to the California Historical Radio Society for their fabulous and invaluable online archive of material relating to American Marconi stations and for productive personal correspondence about Bolinas station.

Diolchaf i **Jason Davies**, Athro mewn Cymraeg a Llenyddiaeth Gymraeg yn Saesneg, Prifysgol Bangor, am ei gymorth gydag elfennau o'r llenyddiaeth sy'n gysylltiedig â gorsaf Marconi.

A big thanks to my daughter, **Ella**, MW6PYS, for her fabulous Edwardian-inspired graphic, and my son, **Ptolemy**, for his capable fieldwork on Mast 13 remains.

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> “We are just entering what may be called, 'the field of vibrations', a field in which we may find more wonders than the mind can conceive of”.
>
> Guglielmo Marconi.

Introduction

There is no doubt that, much to the shame of the Welsh nation, the Marconi wireless station at Carnarvon has been very badly served over the nearly nine decades since it was dismantled. Time and again, understanding and appreciation of this globally-important industrial heritage site has been severely hampered by a lack of knowledge about wireless needed to understand what was – and remains – to be seen. Countless licenced amateurs and professionals were there to be asked for help. But none, it seems, were. Then again, none of those people who did have the knowledge made any real effort, either.

The site is still not widely known within Wales and has, remarkably, never been granted protection under the Ancient Monuments and Archaeological Areas Act 1979, despite at least one report of 2016 assessing it of national and international importance and recommending scheduling. The present work has reminded Cadw of this, but lack of resources has continued to result in inaction. Earlier recommendations for listing of the Marconi buildings has also been revived by this study, though some elements, such as the power house, are already modified to the point of listing being rejected.

This, then, is the attempt to improve matters considerably. It is the output of a year of fieldwork and archive research over a longer period, conducted by a licensed amateur radio operator – me – generously aided, as necessary, by others who appreciate wireless history from across the globe. This brought, for the first time to this important site, a breadth of expert technical knowledge and experience to provide a high-quality, fully-evidenced account of the station.

Most of the work took place during the summer of 2022, to find, record and interpret physical antenna and associated remains at the 1914-1939 Marconi high power, transatlantic radio station at Caernarfon (then universally referred to as ‘Carnarvon’ by the Marconi company). It evolved into much more.

It was not the aim of this work to provide a detailed analysis of transmitters at Carnarvon; the work on the vast antenna site was work enough. But photographs of the transmitters used, together with a contemporary account by the Marconi Company are included as is, for now, a limited consideration of the Towyn receiving site.

Past studies of the site have never really sought to explain nor recreate the layout of the antennas *as they appeared and were used* at the time; they were largely find-and-record exercises. They missed a very large number of remains whilst misinterpreting others, in several cases, seriously so. There is no indication that those surveys examined the Marconi archive, where important details about the site are revealed, significantly informing and assisting fieldwork. Indeed, despite a pre-publication production of this text to Cadw, the subsequent assessment for protection ignored the corrections of earlier mistakes and simply repeated them! Something is *very* wrong with the official Welsh heritage bureaucracy.

The site of the 1923 antenna extension, in particular, presented formidable surveying difficulties. Thigh-high heather and Bilberry bushes across large areas makes progress along the steep terrain extremely hard, substantial concrete remains being well-obscured by the vegetation. Where there is less heather, there is mobile bog and thick layers of moss that are even better at covering things up. In many cases, the present survey found remains only by use of intuition and, often, counted strides based on what could be expected from less obscured features at other, clearer locations on the site. In some years, heath fires may clear the site such that remains once again become more obvious. Even then, the accumulation of up to a foot of peat over some structures means that much of the detail will soon become permanently hidden from view. Even the substantial concrete base of the 1914, Mast 4, has already been entirely consumed by about 30cm of mobile bog.

Almost every feature noted on the Google Earth-based map separately accompanying this text has been visually confirmed and its position logged. No assumptions are made, except where it is clear that the found remains paint an unambiguous pattern and/or where photographs provide the detail not now easily available from the ground.

Place names, measurements and politics.

The station under examination was always referred to by Marconi and his company as the 'Carnarvon' station, which was the then common-usage, anglicised version of the Welsh placename, Caernarfon. In order to maintain coherence, 'Carnarvon' is, acknowledging the unpalatability it may present to some, used throughout this report. Readers searching for historical material about the station will find very little indeed by using the modern, Welsh version of 'Caernarfon', as that form was simply not in contemporary use in English language documents. The press also widely used 'Cefndu' or 'Cefn Du', 'Waunfawr' or 'Waenfawr', or 'Ceunant' as names for the station. The important point is that the Marconi Wireless Telegraph Company never did. Suggestions to the contrary by Cadw, clearly relying on the poor text of Hari Williams (*Marconi and his Wireless Stations in Wales, Gwasg Carreg Gwalch,* 1999) are both ridiculous and, sadly, all too predictable.

Similarly, the receiver site then referred to as 'Towyn' is the placename maintained in this report. There have been long debates about which form – 'Towyn' or 'Tywyn' – the town's name should properly take. A referendum decided upon the latter form in 1968 – some 45 years *after* the receiver antennas had been dismantled. Consequently, anyone searching for records about Towyn should use that form, as the alternative will, again, very considerably hinder progress.

Ultimately, this is a document dealing with the history of technology, not toponymy and politics. That a wireless station located within Wales was almost universally described as being within England and that, rather than go to the effort of using the correct, Welsh form of placenames, a typically lazy, anglicised form was used instead, tells us much about the imperial attitudes towards Wales at that time. Indeed, the whole enterprise of the chain of wireless stations to be built in the mid-1910s was known as "The Empire [or Imperial] Scheme" (e.g. *The Marconigraph*, April 1912, p.4-8). To simply placate the modern sensitivities of some would be to erase important information – at which point the work would cease to be a valid academic treatment. We would never rename Lord Carnarvon, and we would not refer to the Roman settlement of Segontium as 'Caernarfon'.

For fieldwork, and in this report, the British imperial measurement system of feet and inches (denoted by ' and ", respectively) is used, because that was the system then in use by the engineers and men who built Carnarvon—although wavelengths were always given in metres, even then. For a limited number of remains, it was more sensible to either use metric measurements or a mixture of imperial and metric, as suited the materials presented.

In recent times, attention within Wales has come to rest on Guglielmo Marconi's political inclinations, which were clearly, by his own admission, to strongly support Italian fascism. His speech on being appointed by Mussolini as a member of the Fascist Grand Council, if nothing else, made his stance clear:

> "I reclaim the honour of being the first fascist in the field of radiotelegraphy, the first who acknowledged the utility of joining the electric rays in a bundle, as Mussolini was the first in the political field who acknowledged the necessity of merging all the healthy energies of the country into a bundle, for the greater greatness of Italy"
>
> Franco Monteleone, La radio Italiana nel periodo fascista: studio e documenti, 1922–1945, Franco Monteleone, 1976, p. 44.

Marconi's conformity with Mussolini's developing antisemitic regime in blocking Jews from entering positions in the Reale Accademia d'Italia (Royal Italian Academy) he headed have been known since 2002. It seems to have taken twenty years for Cardiff Council to realise this before recently ditching a plan to install a statue to celebrate Marconi and his early experiments in Wales.

Though by no means universally so, embrace of fascism was the tendency for those of Marconi's class, wealth and stature across much of the western world at the time. Where fascism would ultimately lead to was not always clear. Whilst it is always necessary to know of and note Marconi's fascism, his undoubted path towards antisemitic prejudice seems more nuanced – as indeed Annelisa Capristo, author about Mussolini-era antisemitism within the Academy, acknowledged in 2002 (*The Guardian*, 19/3/2002).

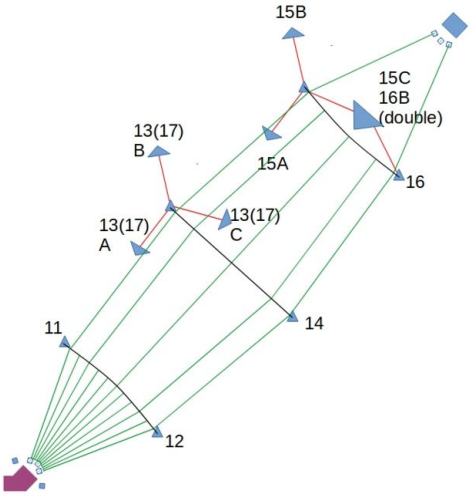
Marconi, perhaps, was less innately antisemitic as he was willing to go along with it as part of the wider fascist movement, though it hardly paints him in a positive light, given that he had the position and wealth, had he wished, to entirely reject Mussolini's regime.

The Jewish Telegraphic Agency of July 23rd, 1937, reporting on Marconi's death, recounted how he had "praised the 'exceptionally large' contribution of Jews to the development of wireless and in other fields of science" and how he had singled-out a number of individuals by name for their "yeoman work in radio", though they did not then know of his activities at the Academy. The original bulletin is available at the JTA web site – http://pdfs.jta.org/1937/1937-07-23_293.pdf

Ultimately, Marconi was the conductor of an enormous, global orchestra of engineers and scientists who developed a successful, commercial wireless system that was the birth of the modern radiocommunications age. Part of the traditional Marconi hero-worship, this text certainly is not.

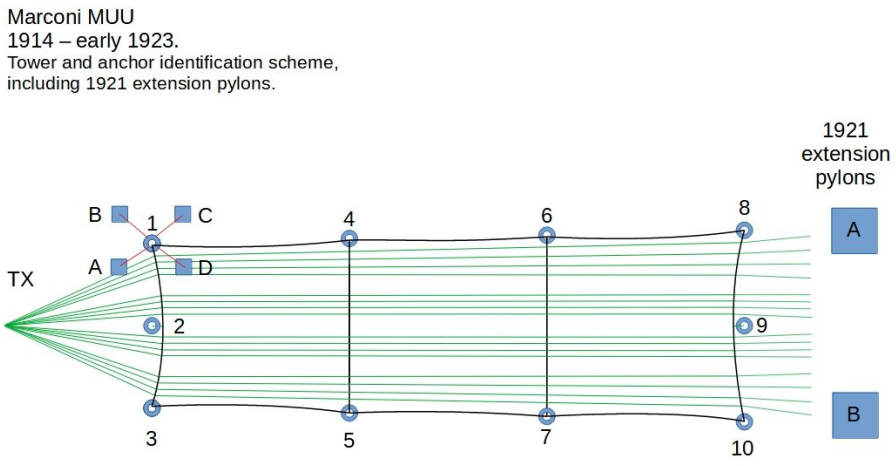
Mast Identification.

The original mast and base identification system for the 1923 antenna extension, often referred to my Marconi's as the 'upper array' or 'N°. 2' array, can be reliably deduced from consistently-labelled photographs of the site under construction. This system is preserved as indicated in the simple schematic.



1923 extension/'upper array' mast and anchor identification scheme (as used by Marconi C°.)

No reference to the mast identification system for the 1914 ('lower array'or 'N°. 1') and its *ca.* 1921 extension was found during this research. A numbering system has therefore been applied according to the schematic below, which is derived from the 1923 array scheme:



Note that most later accounts of Carnarvon ascribe a specific callsign to each antenna. After the 1923 changes, this was unlikely to be correct at all times; N°. 1 (lower) and N°. 2 could be connected to different transmitters and also possibly still act together as one antenna when required. N°. 3 seems always to have been connected to only one transmitter – GLJ. Accordingly, antennas should be identified only by their numbers, 1, 2 and 3 to avoid confusion.

Referencing.

A somewhat non-standard form of referencing of sources is used in this text, which provides the full details of the source immediately following the referenced information, rather than a reference number with the source detail appearing elsewhere. This makes it easier to check those references as the reader progresses.

As noted in the main text, the account of Carnarvon's antenna developments by Vyvyan in his 1933 work, *Wireless over Thirty Years* (republished in 1974 as *Marconi and Wireless*, EP Publishing), is extremely brief and poorly written. The 1999 book, *Marconi and his Wireless Stations in Wales (Hari Williams, Gwasg Carreg Gwalch)*, cited widely in the official historic environment records of Wales, can be fairly criticised, at least as far as the brief discussion of Carnarvon is concerned, as a modern, light re-hash of Vyvyan's work; it contributed nothing to further understanding and ensured errors by Vyvyan, recognised as such many decades earlier, were repeated to a popular audience for over two decades. For those reasons, whilst Williams' book has been examined, it has been almost entirely dismissed as being of any value to understanding the Carnarvon site, and its use by others should be with considerable caution.

Carnarvon Station Timeline

Carnarvon was often described by Marconi as his 'experimental station'. Whilst Marconi was only ever a fleeting presence at any given location, he certainly visited the station, though how many times is obscure. If press reports are anything to go by, it may well be that he only ever came during a series of visits, said to be so "frequent" as to make Marconi a "familiar figure" in the area (*North Wales Chronicle and Advertiser for the Principality*, May 22, 1914) between 1913 and 1914, at the time of its construction – during one of which he was accompanied by Prince Potenziani, later the second fascist governor of Rome (*Caernarvon and Denbigh Herald*, 8th May, 1914) and sixteen Russian scientists (*Yr Herald Cymraeg*, 12/5/1914, p.5).

The Marconi archives show that Carnarvon was important in determining the effectiveness of early transatlantic signalling, notably how well it compared to the German, Nauen station – a reflection of political and business tensions of the time. Similarly, the effectiveness of the various stages of transmitter development were assessed through the use of Carnarvon, culminating in thermionic valve tests during the middle part of its 25-year existence.

To quote a *ca*. 1922 Marconi Co. pamphlet about Carnarvon: "The history of the Carnarvon station is, in large measure, the history of the Marconi Company's work on high-power transmitters…" (*The Marconi High-Power Wireless Station at Carnarvon*. MS.Marconi.198)

Late 1912: land acquisition. No substantive construction.

February 1913 – March 1914: construction, initially by *ca*. 100 men, later far more, and commissioning phase of an 'inverted-L' antenna of ca. 752'-long sloping vertical wires, leading to 2,685'-long horizontal wires which then sloped a further ~400' to rear tensioners (a total of ~3,837'). Earth screen wires buried 6" in the ground, extending to the outer bases and 1590' beyond the then eastern limit of the antenna, reaching within 66' of the eastern property boundary. Simple disc spark dischargers in use. Initial tests in spring 1914, with Glace Bay acting as receiver ahead of Belmar's completion, use 5000m wavelength, moving by June to 11,140m by day, 5800m by night.

1914, August: site taken over initially by the Post Office then, shortly thereafter, the Admiralty for the period of WW1, guarded by the military. Antenna operates with no known modification until *ca*. 1920.

June 1916: Installation of timed disc spark dischargers. 11,100m wavelength used throughout the 24-hour period from now on.

1918: Poulsen arc transmitters installed as emergency backups; arcs found to be unstable.

1918, September 22nd: first ever direct, non-relay messages by wireless, using 200kW input from a timed disc transmitter, between UK and Australia (Carnarvon and Wahroonga, NSW). Wavelength now used is 14000m. Successful test transmissions almost certainly took place weeks or more before the official 'stunt'.

1919: Experimental work with beam antennas began, progressing rapidly to 3m wavelength beam experiments. Beam work moved to Portsmouth in 1922.

Between 1919 and mid-1921 (exact date unknown): Addition of elevated earth screen (counterpoise) supported at a mean 24' on small steel lattice towers extending to the outer anchor limits of the antenna (and not beyond them), and to very close to the eastern boundary of the property, as previously. Stranded silicon bronze wire number reduced from 32 to 20. Wavelength in use as of February 1920 was 14,200m.

Between late 1921 and 1922 (subsequent to counterpoise installation): linear extension of the original antenna by ~500' to the east, giving total wire length of 4,337'. Two large, self-supporting lattice pylons, 60' on a side at their bases, built directly uphill of the final 1914 masts, support the wires.

1921, April 24: Alexanderson transmitters first used.

1921, October: Timed disc dischargers now obsolete and dismantled. 30-valve transmitter installed during the year, under test operation by end of August.

1922: Valve transmitter now used for regular traffic, alongside Alexanderson transmitter.

1923, May: Operation of service from Towyn discontinued as the receiver station closes. Carnarvon now keyed from Radio House, Wilson Street, London. In the same month, a new, water-cooled valve transmitter is installed at Carnarvon.

1923: Possibly catalysed by an increase of over 100% in Carnarvon traffic during 1922 due to seizure of transatlantic cable stations in the Irish Free State, construction, in service by December of 1923, of a new extension to the 1914 antenna. Of ~2,910' total wire length, it ran towards Llyn Padarn to the NE, using six new, 400' three-sided steel lattice masts. The two, ~1921 extension pylons dismantled shortly beforehand. Construction of double antenna tuning inductor house between the two antenna arrays, and a single ATI building at the lower, Llanberis end of the 1923 extension. 1914 and 1923 antennas thus operate, by December 1923, as one antenna, fed at the far western end only. Also includes elevated counterpoise system extending typically 320' beyond *each* side of the support masts for the 1923 extension.

***ca.* 1925:** A splitting of the extended antenna. The 1914 antenna becomes its own antenna again ('N$^{o.}$ 1'), but more a half-loop form than inverted-L as it previously had and without use of the rear straining poles and weights, now cut down. The 1923 extension also becomes an independently-operating antenna system ('N$^{o.}$2') with a new feed from the transmitter for it laid over telegraph poles to the double ATI building. Each antenna has inductors at either end, both during this and the earlier, 1923- *ca*. 1925 period. Both antennas were thus of half-loop general form. A remote-controlled switch at the double ATI house allowed antennas 1 and 2 to operate separately or together.

Mid-1925: Planning for a third antenna ('N$^{o.}$3') initially intended to operate at 7800m, operated from the transmitter circuit, callsign 'GLJ'. First tests in May 1926. No physical evidence for this was found on the ground, but 1926 archive documents show it was installed parallel and very close to the northern end of the 1914 (N$^{o.}$1) antenna. Considerable difficulties experienced with GLJ/No.3 due to proximity interactions (lying 150ft or less from N$^{o.}$ 1) and excessive magnifier condenser potential. Planned for conversion to shortwave use, but not ultimately pursued. Later operated at around 4400m. Problems not fully resolved until February 1927, when GLJ began handling traffic.

1927: Completion of the Imperial Beam System of directional, short wave network of stations marks the beginning of the end for Carnarvon, though it is still in demand for relief work and for when geomagnetic conditions are at their most disruptive; solar cycle 16 was then close to its peak (April 1928), though it and the preceding cycle (peak of August, 1917) proved to be much weaker than later maximums of the 20th century.

1928: Under a Post Office merger scheme, prompted by competition between communications methods and their providers, Marconi's Wireless Telegraph Company – and Carnarvon station – becomes part of the operating company of Imperial and International Communications, Ltd. In 1929, through a share exchange, Marconi's becomes part of the public merger company, Cable and Wireless, Ltd.

1937, 20th July: Guglielmo Marconi dies in Rome, aged 63, after a series of heart attacks. Mussolini grants and attends a state funeral.

1938, November: Carnarvon makes its last transmission following an order to to idle the station for two months, to see if other stations could cope without its services and subsequent decision in October to close the station as part of a 'concentration' (cost-cutting) exercise.

1939, February: Postmaster General announces Carnarvon station scheduled for closure. By early summer, the station is being dismantled and materials thoroughly salvaged. Mostly only concrete and fragments of ceramic insulators remain.

1939 – 2024: The UK and, later, Welsh public heritage authorities afford neither scheduling to the Marconi Carnarvon site, nor listing to its remaining buildings. A call in 2015 by Gwynedd Archaeological Trust to protect the site, referencing an earlier, 2008 report, is not acted upon by Cadw, which has quietly stopped scheduling owing to a lack of resources (pers. comm., Cadw to Rowlands, 8/11/2022). The author of this report formally revives the requests for both scheduling and listing. Cadw eventually accepts it is still only scheduling sites under imminent development threat, saying the planning system should be sufficient protection for now. The author questions the value of the scheduling system as currently operated by Cadw.

The Daily Mail, December 19, 1921.

Wonder Phials.
THE NEW WIRELESS.
VOICE ROUND THE WORLD.
FROM FOOT OF SNOWDON.

High up among the bare, wind-swept Welsh hills I found the voice which can speak to the whole world at once, writes a correspondent in the "Daily Mail."

It is the great Transatlantic Wireless Station at Cefn Du, a few miles from Carnarvon, in North Wales, and on the foothills of Snowdon. A few days ago it sent for the "Daily Mail" a direct wireless message half round the world to Australia.

This was the first direct wireless message sent from Great Britain to a private person in Australia. Inside a brick building at the foot of several great steel aerial masts 400 feet high I saw the strangely fascinating device which can send wireless signals to the other side of the world in one-sixteenth of a second and in the time taken to strike a match can completely surround the earth with an envelope of electric waves.

HOME OF THE WONDER-VOICE.

Picture a luminous wall of large bottles of thin glass glowing with a subdued light— a curiously ghostly radiance, steady and unwinking! Such is the wonder-voice of Carnarvon.

There are 56 of these bottles, each nearly the size and shape of a Rugby football with a slight bulb at each end. and they are fixed in four long rows in a steel frame some 15ft long and 10ft high.

In a complicated tangle of glass tubes and white porcelain insulators and wire covered with emerald green and orange non-conductive fabric, these magic india-rubber air tubes, these magic dials glow, and so, quietly glowing, can whisper at the same moment to Persia and Tasmania, to Alaska and Peking.

These 56 glass bottles of light are the thermionic valves which cause the electric oscillation necessary to radiate a wireless wave across the earth. They take the place of the roaring blue spark of the older day, and when they speak across the world show no signs of their colossal power, but glow as gently and as evenly as ever.

ONE MAN TAKES CHARGE.

Behind these rows of fat glass bottles, which seem like the glowing retorts of some strange chemical experiments, a coil of thick insulated wire waves round about a circular wooden frame which stands on porcelain pillars. This is the "aerial inductance" and on another frame, which completely

surrounds the first but is entirely separated from it, is a coil of similar wire in red insulation. This is connected to the valve, and the impulse which sends a film of energy about the whole earth in a moment of time travels from the radiant bottles to the aerial across a bridge of air.

The room was luminous with the soft light of the valve, and there is scarcely a sound save for the even drone of the dynamos operating the set. This was a magician's chamber of 1921, where, by pressing a tiny key, one might circle the globe in a moment and send commands to all the four corners of the earth at once. "This valve transmitter is the largest in the world, and has only been completed in the last few months." said an official of the Marconi Company who was showing me the wonders of Carnarvon. "The great value of this transmitter is that it is capable of girdling the earth with the same power which hitherto has been necessary to send messages to the United States.

"The new apparatus is not yet finally installed, but will be ready for the commercial service in a few weeks."

"How many men are required to take charge of this apparatus for sending a message round the world?" I asked him.

"One," he replied. "And he would have comparatively little to do. He would merely have to keep an eye on the working of the set, which would be operated by automatic transmission from our transatlantic receiving station at Towyn, some 45 miles away."

PL202

THE MARCONI HIGH-POWER WIRELESS STATION AT CARNARVON

MARCONI'S · WIRELESS · TELEGRAPH COMPANY, LIMITED

MARCONI HOUSE, STRAND, LONDON, W.C.2

Telegrams : EXPANSE, ESTRAND, LONDON. Cables : EXPANSE, LONDON

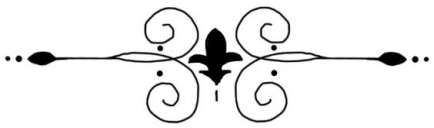
'Phone : CITY 8710 (15 lines).

Codes : Marconi. Western Union. Bentley's. A B C 4th and 5th Editions.

ca. 1922 cover page of a Marconi's promotional pamphlet. Bodleian Special Collections MS.Marconi 198.

“It was rather like proposing to build a cathedral in a world which had never seen anything more grandiose than a log hut.”

Marconi Company historian, W.J. Baker, on Marconi’s proposals to the board to build his high-power stations, of which Carnarvon was one. Cited (p.147) in *Marconi, The Man Who Networked the World*, Raboy, 2016, Oxford University Press



The Official Record To Date.

A plot of features from the Gwynedd Archaeological Trust's March, 2016 Report 1302 (*First World War Military Sites: Manufacturing and Research and Development*) shows what was known of the Marconi Carnarvon site as of May, 2022. Whilst there was an emerging picture of something more extensive than simply the well-recognised, first, 1914 antenna, surveyors lacked the knowledge to link most of the remains to function. Expected later official surveys seem not to have taken place for some reason. A very large number of remains were not detected by these surveys, mostly as they failed to seek patterns in things like the earth screen/counterpoise base positions, arising from that lack of knowledge of wireless systems, and a failure to consult the Marconi archive. On more than one occasion, ridiculous failures in interpretation of substantial and important features came to be recorded in the official account of this globally-important site.

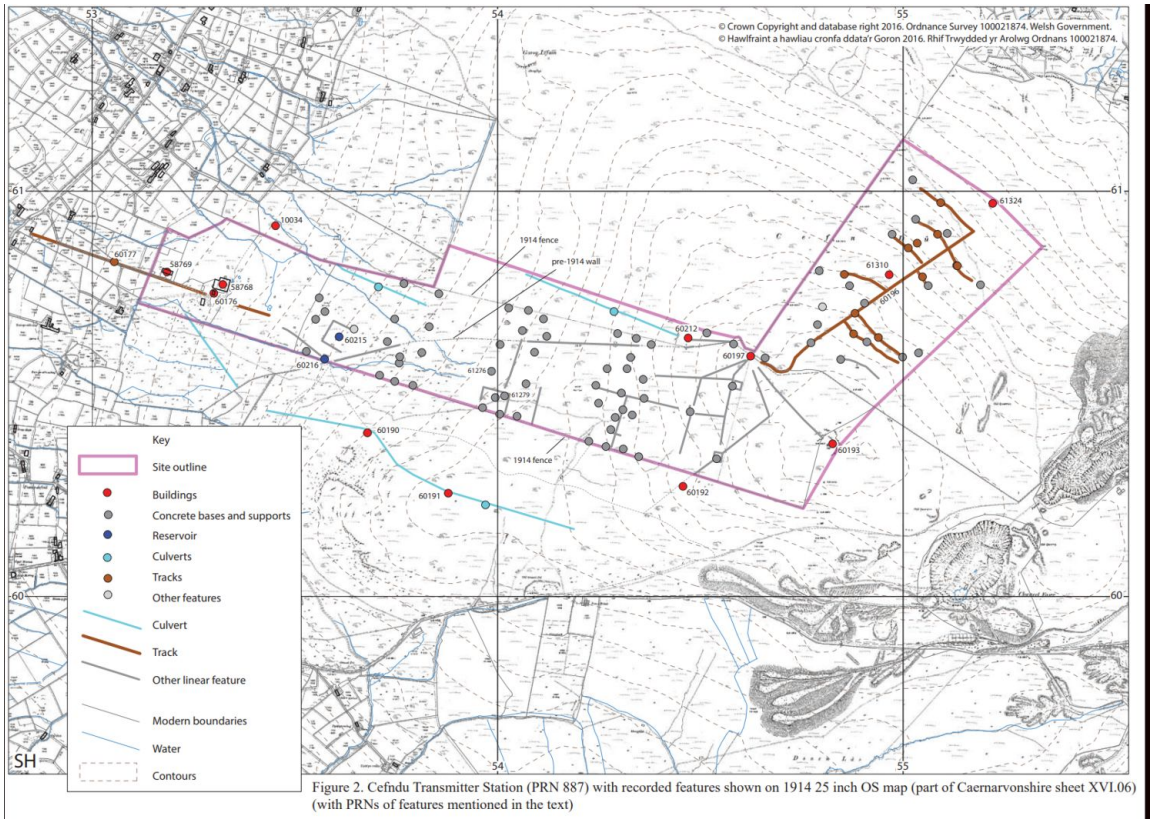


Figure 2. Cefndu Transmitter Station (PRN 887) with recorded features shown on 1914 25 inch OS map (part of Caernarvonshire sheet XVI.06) (with PRNs of features mentioned in the text)

1. *Archaeological survey plot of the Marconi Carnarvon station site, an extract from GAT Report 1302, March 2016. The site boundary (pink) cannot be relied upon in relation to the 1923 extension (to the NE) , as antenna structures exist beyond it.* Via *GAT, Crown Copyright.*

Some detail, including photographs in many cases, of individual remains depicted on the map appears on the *Coflein* online database of archaeology, buildings, industrial and maritime heritage in Wales – coflein.gov.uk – and may be freely interrogated by the public. In 2023, the present text became the basis of a major overhaul of the information presented by *Coflein* about the Carnarvon site, this text thereby becoming the official reference work.

2022 Study of the Carnarvon transmitter site.

The Carnarvon Marconi site, occupying some 110 ha when its guarding blockhouse perimeter is included, was located on Cefn Du mountain, the first antenna and transmitter buildings built between spring 1913 (report of station plan submissions to Gwyrfai District Council, in *Y Llan*, 28th February, 1913) and spring 1914 (*Marconi and Wireless*, Richard N. Vyvyan, E.P. Publishing, 1974, p.62 – a later edition of the 1933, *Wireless Over Thirty Years*, pub. Routledge and Kegan).

The ground at the site was too boggy for horses to haul construction materials. Instead, the material – all ~8000 tons of it – was first brought by rail to Llanrug station. It then went by road to Ceunant, then up a long access road – the form and route of which changed towards completion (invitation to tender for "construction of a roadway about 440 yards in length", *Yr Herald Cymraeg*, 12/5/1914, p.4) – and parallel light railway, leading uphill to the summit of Cefn Du by means of steam haulage engines and steel wire rope (i.e., an incline system akin to those used in the slate quarries of the area, of which one neighbours the antenna site). Definitive evidence of steam boilers and even their coal fuel and clinker was discovered during this work (see p.215). Some 6000 tons went into the mast bases and anchors alone (*The Wireless World*, December 1913, p.536). From where the transmitter buildings came to stand, at the western (lower) extremity of the antenna, an extensive network of track spread out to all parts of the site and its protective blockhouses. Anywhere that concrete had to be poured, or local rock needed to be quarried for trackbed, aggregate or building inclines, as happened extensively here, a track would be sure to go.

Vyvyan, the Superintending Engineer responsible for design and construction of most of Marconi high power stations, but whose personal, on-site involvement at Carnarvon is obscure, asserts (op.cit., p.60) construction had begun in 1912, *before* the District Council had been shown the plans for construction on 28/2/1913. An account of Marconi engineer movements in the February, 1913 edition of *The Marconigraph* (Vol. II, Nº. 23, p.535) asserts that a P. Croker had just returned to Head Office, London, from "preliminary work on the site for the Welsh high-power trans-ocean station". This supports the *Y Llan* article indicating a commencement of construction in early 1913. A detailed report concerning the recruitment of some 40 men from Caernarfon – grateful for the work in lean times – further confirms the substantive start date, seemingly pinning it down to Monday, 24th of February, 1913 ('Work Begun at Cefndu' [sic], *The Herald*, 28/2/1913, p.8, also *Liverpool Echo*, 24/02/1913, announcing "a start was made to-day on the construction..."). The men worked from 7am until 5:30pm Monday to Friday, and 7am until 1pm on Saturday, at an hourly rate of 5d. At least initially, some had to walk four miles to the site, necessitating a 5am start to the journey. Appeals to a local, private bus operator to transport the men to site at the suggested rate of 1/6 per week, per head (£8 at 2021 prices), was an offer the company could not entertain, reported *The Herald* (ibid.).

The initial transmitter station buildings were contracted to Messrs. Holland, Hannen, Cubitt and Cº. of Grays Inn Road, London – a company involved in diverse and important 20th century building projects, including the Cenotaph in Whitehall, and Trawsfynydd nuclear power station. The masts were designed by Andrew Gray (Oxford Special Collections MS.Marconi.219), who joined Marconi's in 1899 (*Graces Guide to British Industrial History*) and their supporting structures were built by Marconi's themselves (MS.Marconi.219). This brought a total of at least 100 men to work on the boggy, windswept slopes of Cefn Du, according to the *Herald* article (ibid.). During the week of 18th August, 1913, the workforce was "augmented by the importation of a large number of Irishmen" (*Caernarvon and Denbigh Herald*, 22/08/1913).

According to *Grace's Guide to British Industrial History*, Harold Borlase Triscott Childs is said to have "erected Carnarvon transatlantic wireless station 1913-1914". Childs is mentioned in MS.Marconi.219 (Oxford Archives) as one of four potential sub-departmental heads for the Empire scheme. Childs was serving in the Royal Flying Corps by 1915, (National Archives, GBM/AIR76/15377) when his involvement with the station must have ended. Childs married a Waunfawr vicar's daughter (see Appendix VI). Childs seems not to have published anything about his work at, or more probably simply on, Carnarvon, a site he may only have dealt with from a distance.

Carnarvon was a transmitting component of Circuit Number 2 in a network of Marconi, very low frequency (VLF) stations that spanned the (colonised) globe. This should not be confused with the way individual antennas at Carnarvon were later identified – also as numbered 'circuits'.

The land, then amounting to some 100 acres (40 ha) was bought by the Marconi Company from Mr. F.S. Barnard, J.P., of Castell Bryn Bras (SH 54339 62588), and Mr. J.O. Hughes, Cae Hoeden – SH 52218 61738 (*Y Llan*, 28/2/1913).

The receiving site for Carnarvon transmissions was Belmar, New Jersey, USA (40.189053° N, 74.064674° W). Carnarvon was the transmitting antenna for this two-component station in north Wales, the receiving antenna system located in (modern-day) Tywyn – always given in the then common-usage alternative 'Towyn' in the Marconi archive – 38 miles, as the crow flies, to the south (E.E. Bucher, *Practical Wireless Telegraphy – a complete text book for students of radio communication*, Wireless Press, Inc, 1917, p.293).

Four wires ran from Towyn along Post Office telegraph poles to Carnarvon to effect the keying of the transmitter (*The Wireless World*, July 1914, p.215). An official notice in the *Caernarvon and Denbigh Herald* (31/10/1913, p.4) by the Postmaster-General, advised of the imminent installation of new poles "along the public street or road from Waenfawr to the Marconi Wireless Station".

Towyn was the receiving site – callsign 'MUV' (*Popular Wireless*, 'Britain's Greatest Station', June 24, 1922, pp. 52-53) – for the transmitter at New Brunswick (callsign 'WII'), NJ, USA; 40.515523°N 74.488852°W (*An Elementary Manual of Radiotelgraphy and Radiotelephony*, J.A. Fleming, Longmans Green and Co., 1916, p.293), with the callsign 'WII' (*The Electrical Plant of Transocean Telegraphy*, E.F.W. Alexanderson, A.E. Reoch, C.H. Taylor, Transactions of the American Institute of Electrical Engineers, Vol XLII, 1923, p.708). Carnarvon transmitters continued to be keyed from Towyn until The Central Telegraph Office (General Post Office) at Radio House, London took direct control in 1923 (Vyvyan, op.cit., p.66), with the closure of Towyn at the same time.

Carnarvon and Towyn were of such notable technological development of the time that a popular, four-volume 'self-improvement' text saw fit to feature photographs of both sites in a chapter dedicated to wireless communications (*The Outline of Science. A Plain Story Simply Told*. 1922, George Newnes Ltd. J Arthur Thomson (Ed.). Vol.2, chapter XXV, pp. 579, 583 and 585)

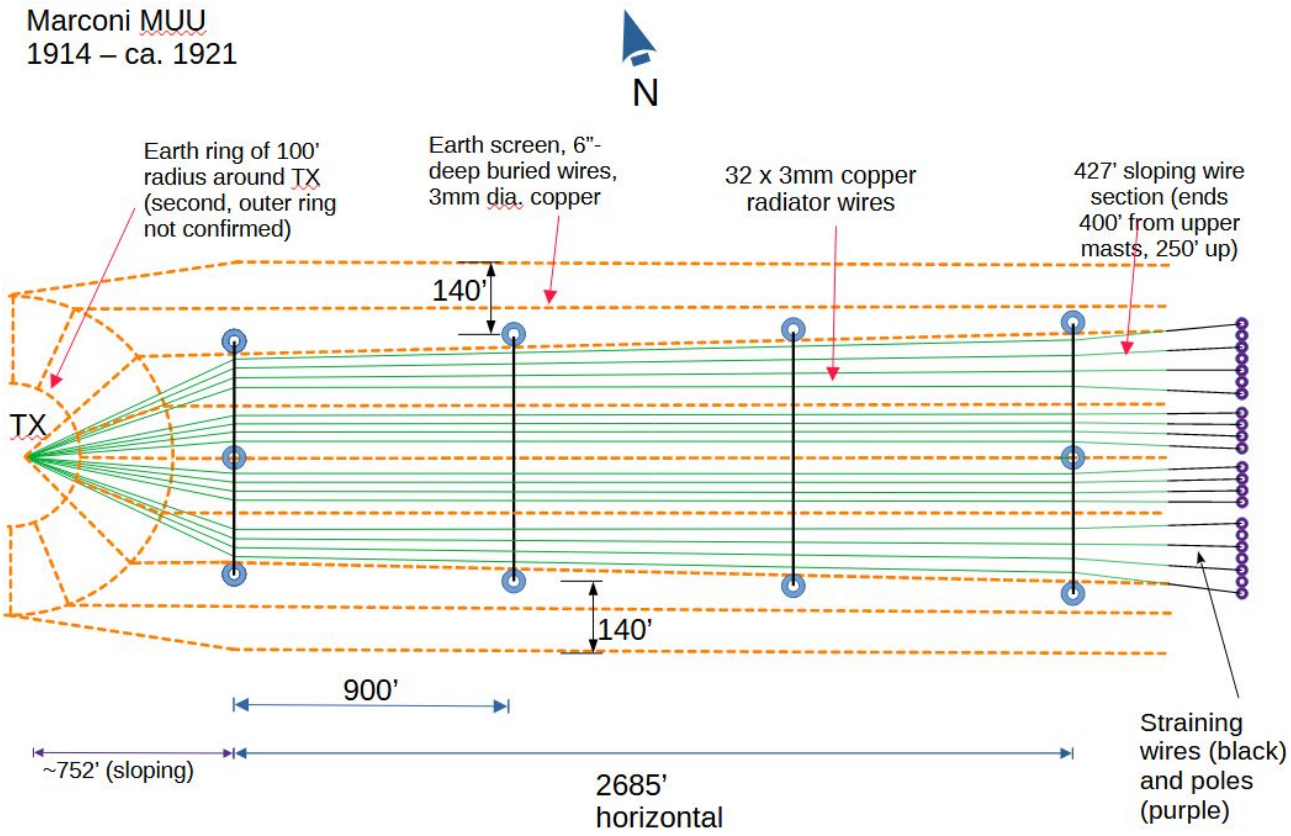
The first, 1914 antenna, callsign: MUU.

The overall form, but not the detail, for the first, 1914 antenna at Carnarvon is readily reconstructed, with little dispute, from images of the time and from remaining base structures. Ten tubular steel masts of 400’ height ran uphill from the transmitter buildings, such that the horizontal part of the antenna wire they supported sloped at a noticeable, 12% mean gradient (328’ total gain in height between lower and upper mast bases) in the case of the 1914, unmodified antenna. The masts were arranged in a 3, 2, 2, 3 pattern widthwise, with the three mast arrangement being at either end of the antenna, the extra mast taking up the additional end loads (see **2**). The radiating wires hung from insulators attached to steel triatic suspension wires, themselves isolated from the masts by ceramic rod and ‘reel’ insulators (see Draft Specifications, Appendix III, p.162).

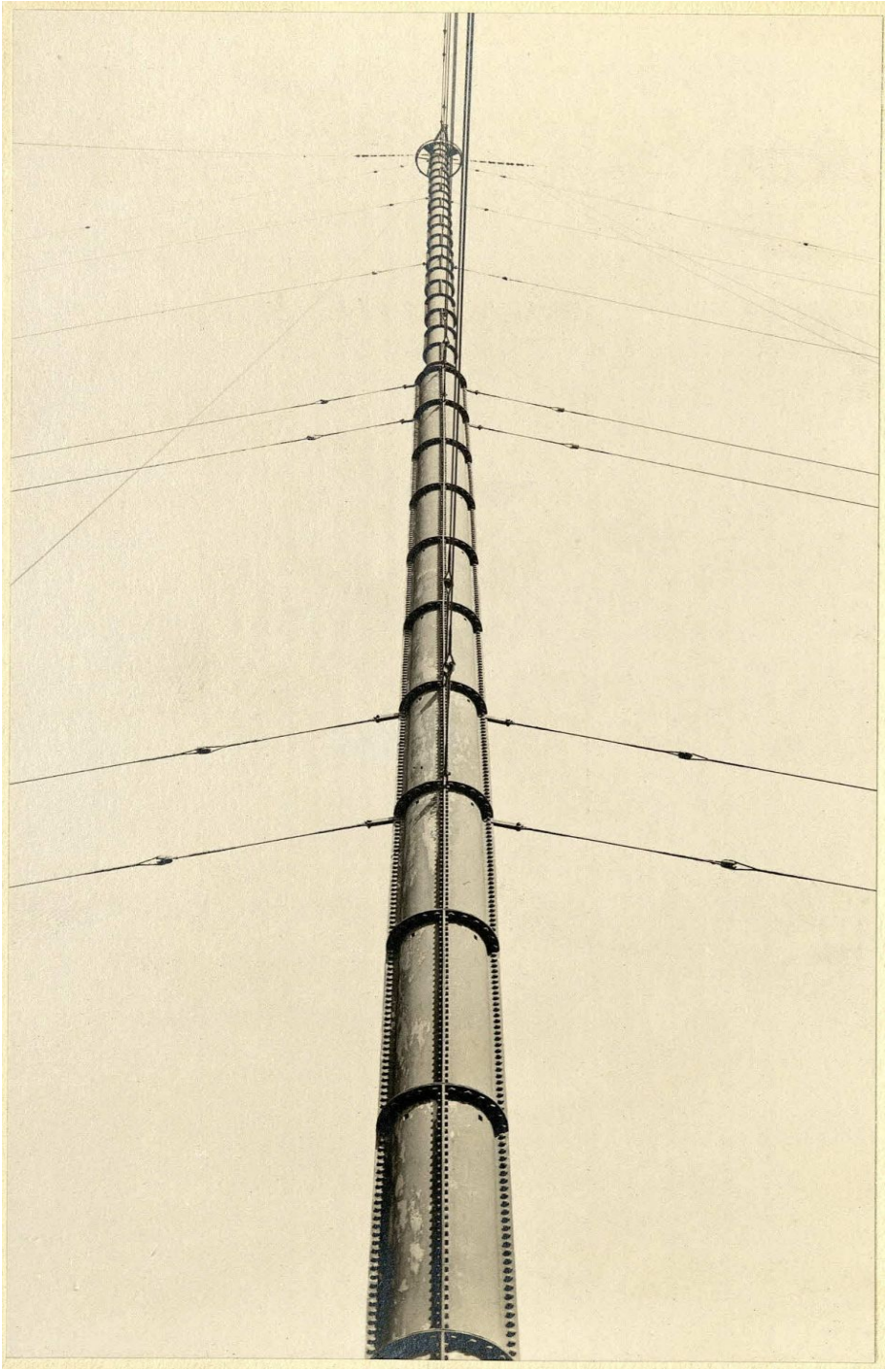
Spacing between the masts in the long direction was a constant 900’. The width of the antenna (between the 2-mast pairs, or outer two masts at the 3-mast ends) increased by a constant 50’ per set, uphill. The outer masts of the lower extremity of the antenna were 450’ apart. The next masts up were 500’ apart. The third pair 550’, and the final outer masts of the upper, 3-mast end, 600’ apart. A Marconi Company pamphlet of *ca*. 1922 (*The Marconi High-Power Wireless Station at Carnarvon*. MS.Marconi.198) describes the masts as spreading ‘fanwise’, an exaggerated depiction of a front-to-rear increase in span of only 150’ over 2685’.

2. *Modern communications technology contrasts sharply with rural ways in this side view, taken in summer 1918 from near Llanrug – almost certainly, from Rhôs-lan (SH 52993 63140), of the 1914 antenna to the south-east, running up Cefn Du. Detail of a larger image from Bodleian Special Collection MS.Photogr.c.243, photograph P.2070 (see also related P.2067, P.2068, P.2069).*

2a. *Rhôs-lan, Llanrug, the stone cottage long ago replaced by a bungalow, looking out towards where the Marconi antenna once stood.*



3. *Simplified schematic of the 1914 antenna, prior to first modification (i.e. pre-ca.1921). There were initially 32 radiating wires, arranged in a 2 x (2 x 8) group, manifesting as an 8-16-8 pattern at the rear strainers, with a gap between groups. Only an indicative number of radiating wires is shown, in green, in order also to show the earth screen wires, in dashed orange. The screen extended in width (N-S) to just inside the outermost anchor blocks and, it seems, lengthwise, to the east, at least as far as the termination of the radiating wires. The row of purple circles to the rear indicate the wire straining poles, now numbering 29 in all; the three missing strainer bases, which would bring the total up to 32, can reliably be accounted for as having been destroyed to make way for the 1923 double ATI building. Locating the 'lost' strainers by measuring 4.5m from each of the centre strainers correctly places them in a coherent plan. Accounts of the antenna can be confusing to the unwary because often, they do not make clear which period of the site they were referring to, may themselves conflate different periods, changes were rapid and often experimental and temporary, and texts were often at least partly based on much earlier writing.*



4. *Sectional, 400' tall steel antenna support mast for 1914 antenna at Carnarvon. Note the stay cables, of which there were 4 x 7 sets, broken up into ~100' wire sections using large, brown-glazed ceramic 'egg' insulators by Taylor & Tunnicliff Co., each weighing ~5.15kg (11 lbs 6 oz). A 7th December 1922 account, written for the journal '*Engineering*', held in the Marconi archive (*MS.Marconi.198*), gives 4 x 5 sets of guy wires, which is incorrect; the July 1914 edition of* The Wireless World *(p.218) is clear that "four sets of seven stays of 3 inch [circumference] steel wire rope with solid core are used for each mast". Note the gallery. The dark sections may be small areas for stepping onto on emerging from the inside of the mast, up which a ladder ran. Later accounts, when the mast tops may have been modified, gave a total length of 412' (*Liverpool Daily Post, *24/5/1939, p.13).*

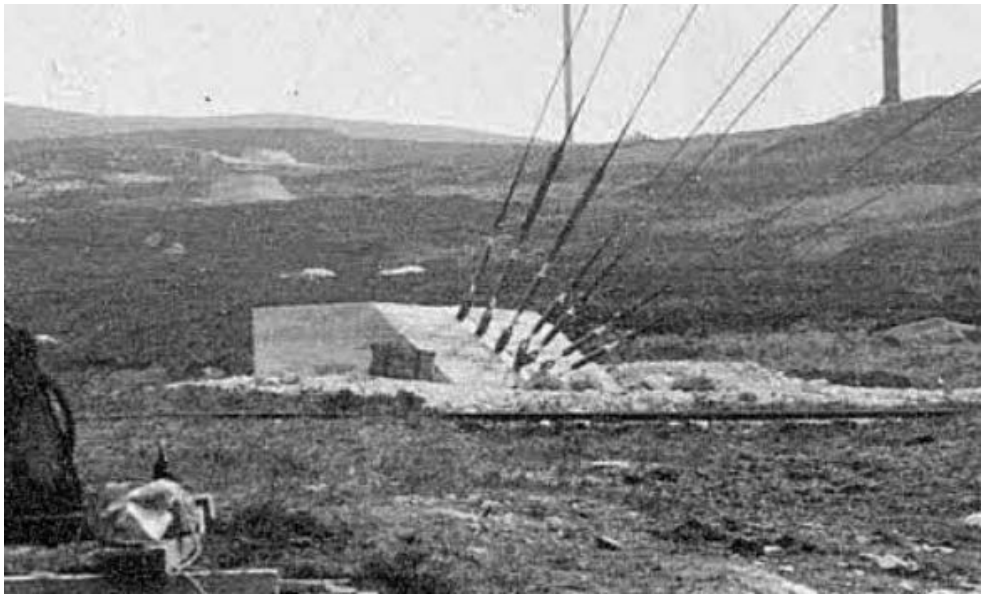
5. *Tread steel plate, with inner and outer curved edges, possibly part of the standing area of a mast-top gallery, potentially Mast 8, which is seen in a 1939 British Pathé film reel ('Felling Wireless Masts at Carnarvon', Film ID: 1013.05, issued 1/06/1939) to fold on toppling, which might explain this plate being found 265', and not 400' from the mast base. Yellow part of tape open to 1 foot. 25¾" long, outer edge 21¾" long, inner edge 9½" long, ½" thick.*

53.123053°, -4.179225°.

The lower half of the masts were of four, steel quadrant sections *per* 15' vertical unit, using 29 bolts vertically to join them. Photographs, never the best quality, nevertheless allow us to be confident that the number of units for roughly half the height of the antenna was 13, whilst the upper half, of narrower diameter, shorter units, made of half-sections rather than quarters, had 20 units of 10' in length (*The Wireless World*, July 1914, p.217). The joint seams of the upper half of the antenna were alternately staggered by 90 degrees. The lower sections are given in the Marconi archive (MS. Marconi. 198) as 3'6" in diameter and the upper as 2'6"; whether this was internal or external diameter is not stated. Regardless, the available space for climbing the internal ladder, accessed through an oval portal at the base (see **12**) was very tight indeed in the upper half of the mast!

A gallery was fitted between the last and next-to-last tube unit at the top of the masts. This seems, from photographs, again of inadequate quality to be absolutely sure, to have had only a couple of steel plates either side of the mast top, rather than a continuous walkway all the way around. A section of tread steel plate was discovered in a position reflecting roughly where the top of Mast 9 might have come to rest (269' from its base) when the site was cleared in 1939. This may well be the tower seen falling, folding in the process (hence the 269' from the base, rather than ~400') to the north, recorded in a 1939 British Pathé newsreel about the demolition, work which was undertaken by Thomas William Ward Ltd., Sheffield – famous in earlier times for hiring an elephant and its keeper to haul trailers during WW1, when horses were in very short supply. The base stud nuts were first cut (see **21**), and then the guys on one side blown with gelignite (**6**), causing the mast to "sway ominously". The steel plates of the masts were sent to the Rhondda Valley for use as water carriers (*Liverpool Daily Post*, 24/5/1939, p.13).

6. *Preparations for stay cutting with explosives (method confirmed in* Aberdeen Evening Express, *24th May, 1939, p.5 and* Liverpool Daily Post *of the same date, p.13), during May 1939. Five stay attachments are seen. Other photographs show seven stay wires. This is explained by two wires being attached, via a trapezoid plate, to each of the lower two anchor attachment rings (plate just visible lower centre). In this image, and in another of the tower immediately before felling, some of the lower stays have already been detached. The projecting thin wires appear to be copper grounding wires (cut) between stays. Image © Reuters* via *British Pathé, still Nº. 7, Film ID: 1013.05, issue date: 1/06/1939, under licence.*

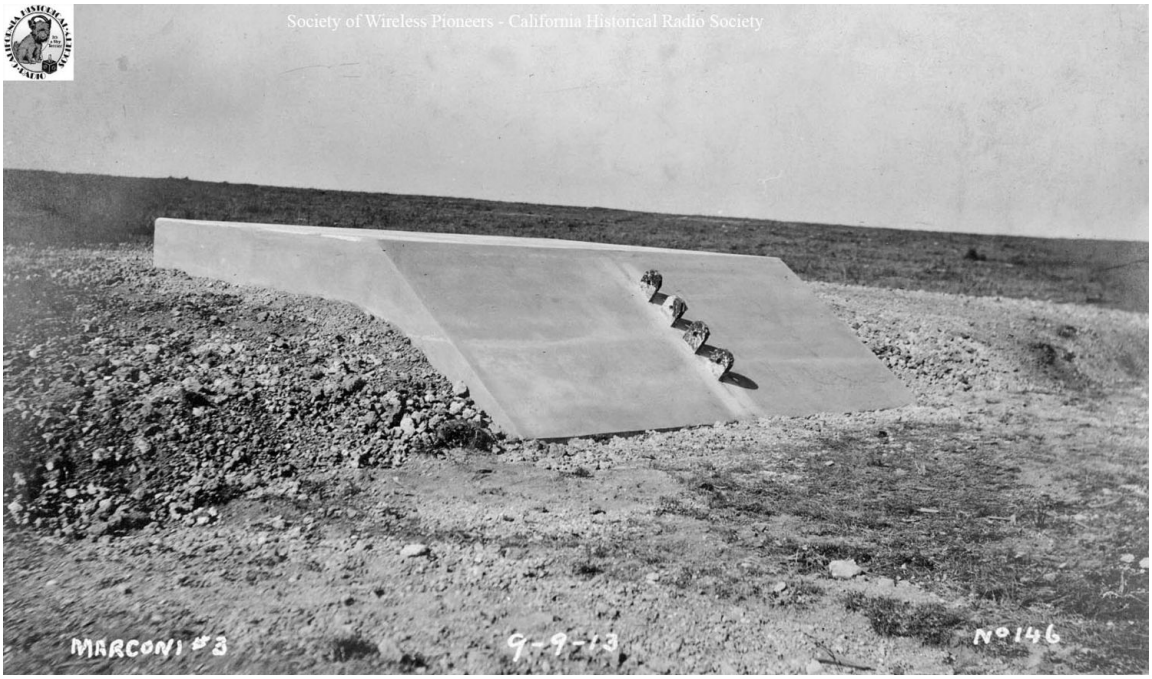


7. *Anchor block (probably 5C), soon after construction, showing seven stays leading from five block attachment points, the lower 4 stays occupying only two attachment rings via the use of a common trapezoid plate for 2 wires each. Detail from a wider view in MS.Photogr.c.243, document 692/x, Bodleian Special Collections.*

8. *Anchor block (6C) and stay turnbuckle attachment points, April 2017.*

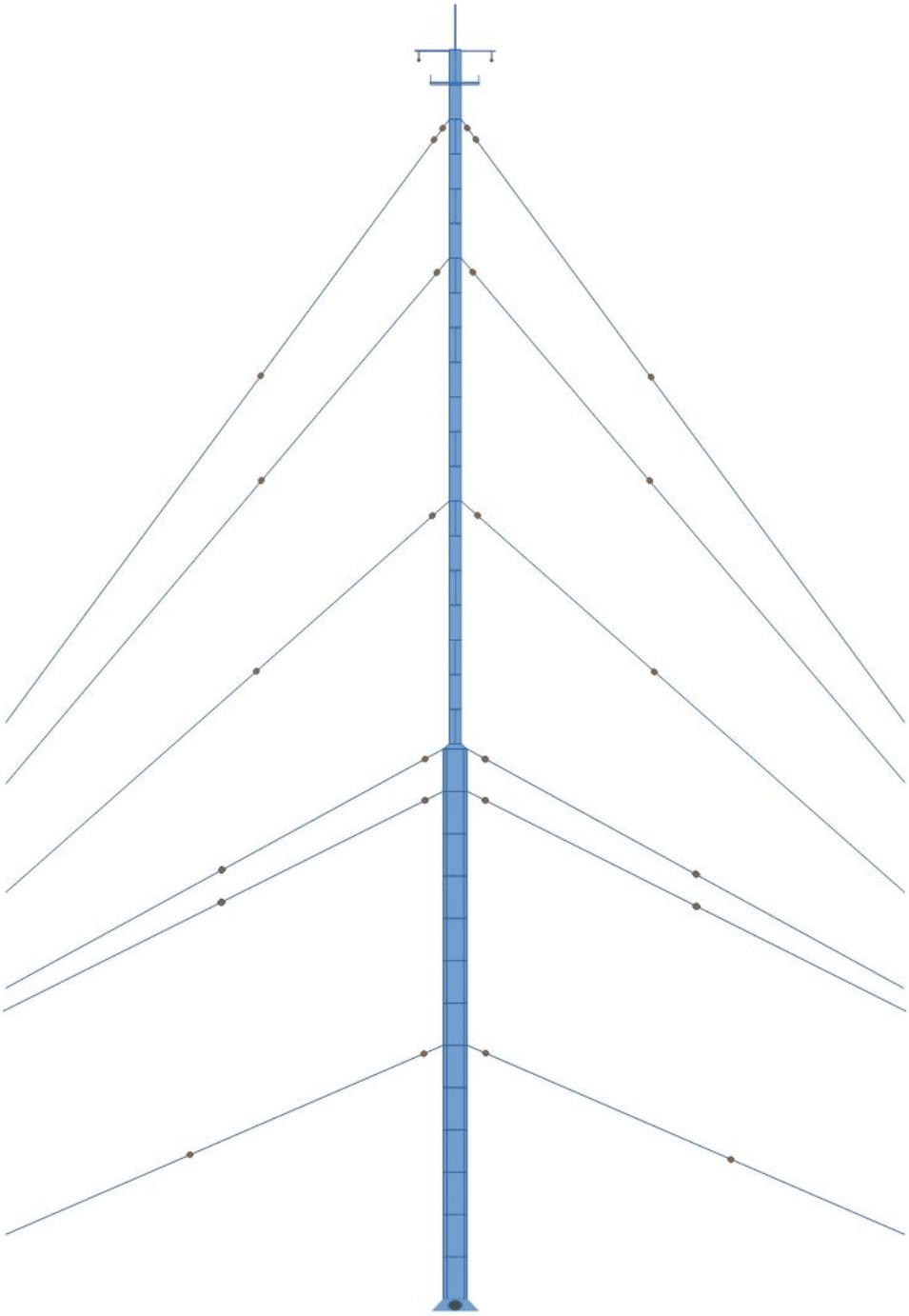
9. *A wider, April 2017 view of concrete anchor 3B, with family members for scale! Transmitter buildings seen in background, centre left. The blocks present a 35.5-37 degree (varies slightly between blocks) sloping face, within which stay attachment points are inserted between and bolted to a concreted-in, ¼"-thick, pair of 4"x4" 'L'-section steel retainers, 7' long (slot between is 1.5" wide). Anchors 143" x 124", height variable according to surrounding ground, typically about 45". Anchor fixings 4.25" long. Their mass, some 98 tons ('Trans-Ocean Wireless Telegraphy, New Transatlantic Service, The English* [sic] *Station Described';* The Wireless World*, July 1914, p. 218) has led to at least two of the anchor bases tipping in the peaty ground; 10D by 3 degrees and 4C by 5 degrees. Anchor 4B is in poor condition, but because of this, allows the internal anchor steelwork to be understood (see* **123, 124***).*

10. *The familiar form, together with trapezoid, two-anchor attachment plates, now blending into the forest taking over the site of Marconi's Marion site, Massachusetts, USA. Image by kind permission of Marian Howell* via *Sippican Lands Trust.*



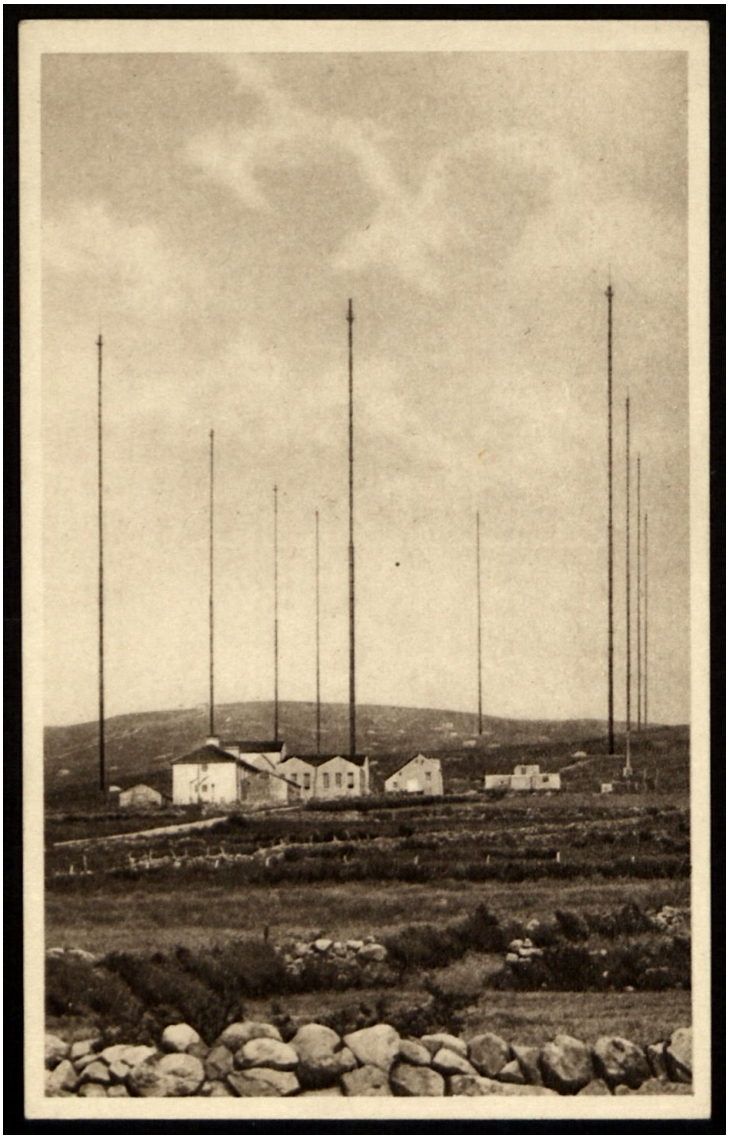
11. *The global span of Marconi's wireless system becomes clear as we find an anchor block of the same form in Bolinas (initially callsigned 'KET'), California, USA, at 5,168 miles from Carnarvon. All US Marconi stations were soon taken over by RCA due to government concerns over control of communications. Date as* per *photo annotation. Image courtesy California Historical Radio Society, which, in 2017, revived the later callsign 'KPH' as a WSPR beacon receiving station on the amateur radio HF bands.*

12. *Central mast (Mast 2) of the first three masts at the transmitter (western) end of the antenna. A hatch is laid open, giving access to the ladder running to the top gallery, within (*The Wireless World*, July 1914, p.218). The baseplate at the concrete (6' diameter stud outer to stud outer) is of 16 threaded studs of 2" OD, with two nuts of 2½" OD securing each. The ¼ section mast elements, each 15 feet long, are of fairly thin steel (see* **129***), perhaps ¼" or less thick, with 29 bolts joining each vertically and 20 radially. Rectangular holes, of unknown purpose but potentially related to the raising mast platform used during erection, are seen in the upper centre of each section – also seen in images of Marion (USA) and Ullandhaug (Norway) masts. The lower part of the mast was 3'6" in diameter (presumably internal, but not known – both referenced accounts fail to indicate), the upper part 2'6" (*The Wireless World*, July 1914, p.217 and Marconi station pamphlet in MS.Marconi.198). Note the 7-stay anchor at rear left of mast and what is probably a triatic halyard, at far left. The item on the floor at left is difficult to identify. The lanyard is behind, rather than connected to it. There are no smaller steel masts either side of the transmitter house at this time. Bodleian Special Collections MS. Photogr. c.243, document P.2092. Date unknown, but pre-elevated counterpoise, and therefore pre-1921, probably around 1918.*



13. *General scheme of a tubular steel mast for the first Carnarvon antenna, looking along the long dimension of the antenna. The stay wires were 'broken up' into* ca. *100' sections (*The Wireless World, *July 1914, p.218). The insulators broke the electrical continuity of the stay wires so that induced currents would not reduce the antenna's efficiency. The arms supporting the triatic wires at the top do not appear in pre-1923 photographs of the masts. They were probably installed in 1923, when the radiating wires were changed from 19 SWG, 7-stranded wire to "N°. 1 gauge" solid silicon-bronze (*The Wireless World *January 30th 1924, p.554). From wire fragments found during fieldwork, it is clear that '19 SWG' (~1mm) referred to the diameter of each strand of the 7-stranded wire; the strands together forming a wire of about 11 SWG (~3mm).*

14. *General arrangement of 1914 mast heads, triatic support wire widthwise between them and insulator supports hung from it. The lower insulators were 'reel' (pulley-wheel) type, through which the antenna wire moved freely to allow for dynamic tensioning from the rear, where triatics had a design breaking strain of 7½ tons (draft specifications appearing in* The Marconigraph, *September 1912, pp. 214-216). The view is looking either up or down hill, along the antenna. This depiction, for clarity, shows just 20 radiating wires, whereas there were 32 initially. Two wider gaps between sets of insulators are inferred from the pattern of the rear wire strainers and the centre gap inferred due to the presence of central towers at either end of the array.*



15. *Carnarvon station as it appeared through the WW1 period, prior to any extension. Original source unknown, but probably Marconi archive; it does not appear to be within the modern Bodleian archive.*

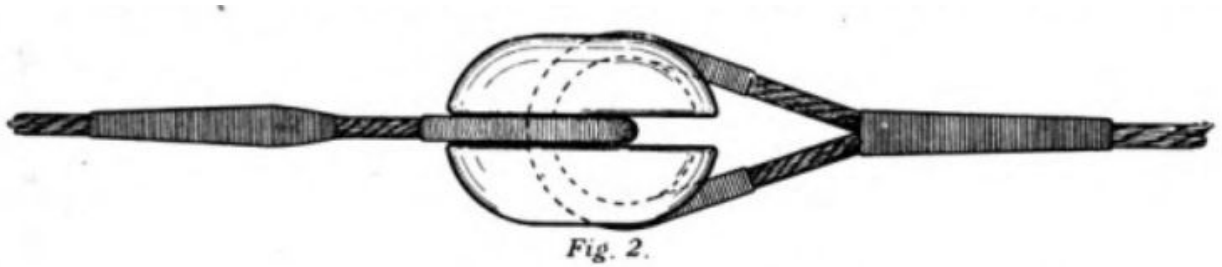


Fig. 2.

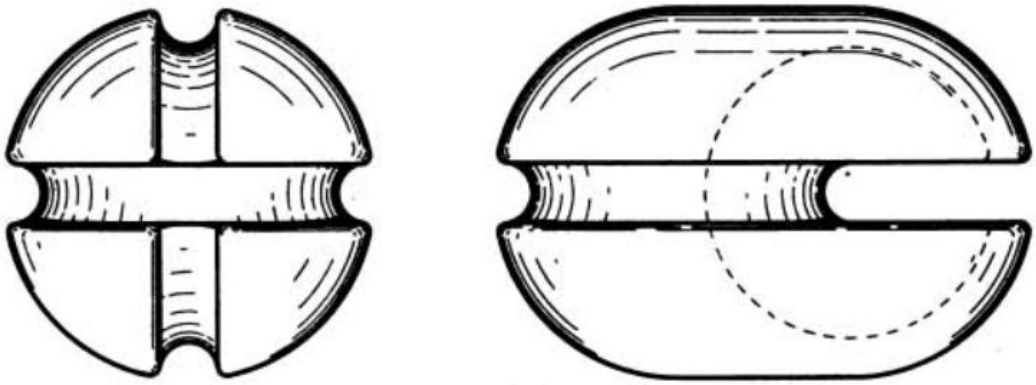


Fig. 1.

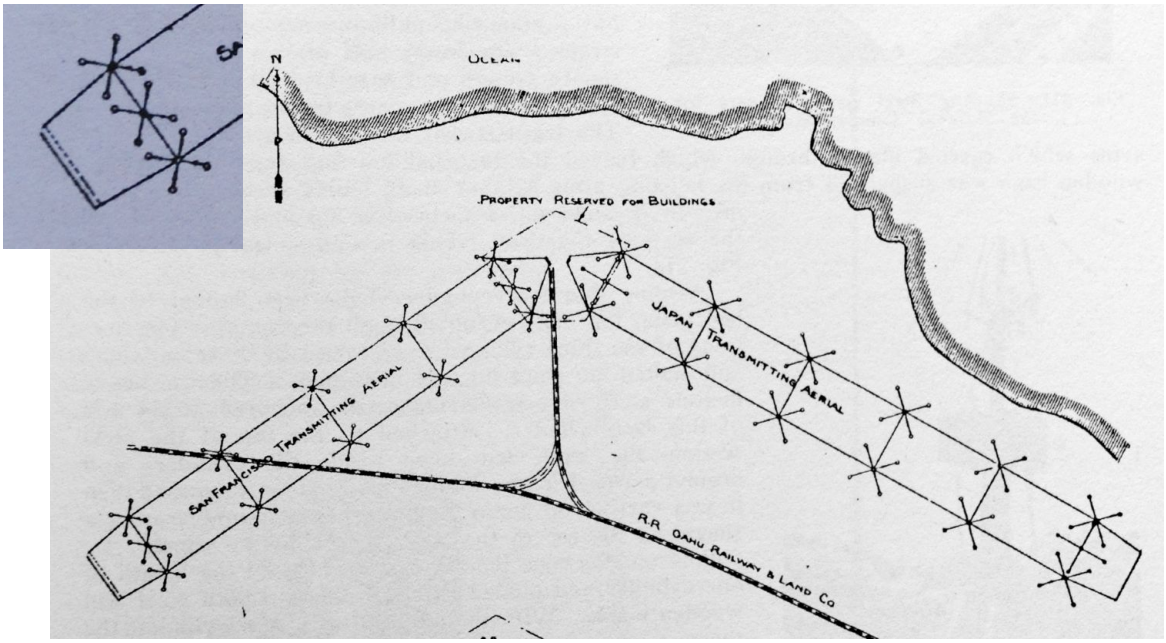
16. *Large 'egg' stay insulators, as depicted in* The Wireless World *('Insulated Joints in the Wire Guys for Masts') April 1914, pp.31-32.*

17. *Recovered, nearly-intact egg insulator, showing Taylor & Tunnicliff maker's mark, centre top. Cable groove width = 30mm, to accommodate 1" diameter (termed a 3" (circumference) cable). Rule = 15cm/6". A small amount of black 'tarline', which gave some 'padding' between insulator and cable, remains on the side faces (not visible).*

18. *Egg insulator remains, identical to Carnarvon, except for the glaze colour, at Marion, MA, USA. Image by kind permission and © of Marian Howell* via *Sippican Lands Trust.*

19. *1" diameter stranded stay cable – usually then termed 3" [circumference] cable – was discovered, buried at the western foot of the octagonal concrete base (see* **108***) during fieldwork. for this study.*

The detailed arrangement of the radiating wires themselves was, initially, less clear, but became informed during research by other sites known to be very similar to Carnarvon. The Marconi archive photographs held at Bodleian Special Collections also quite clearly shows the overall antenna form, although wire runs are always difficult or impossible to see against a typically overexposed sky.



20. *Plan of antennas at Kahuku, Hawaii (Bucher, op.cit., p.299, fig. 310), with inset detail of likely rear straining masts (rear dots) on the San Francisco antenna. Note the three masts at either end, as also found at Carnarvon.*

The Marconi transmitting site of Kahuku on the Hawaiian island of Oahu and completed, as Carnarvon, in 1914 (*Honolulu Star-Bulletin*, September 24, 1914, 2:30 edition, front page), used an essentially identical antenna system of tower supports and wires. Under the erroneous belief in directional radiation (in azimuth) from an inverted-L, there were two antennas here, one intended for communicating with San Francisco, the other, slightly longer antenna, with Japan.

The Kahuku plans by Bucher, Marconi's Instructing Engineer, confirm the directional *intention* of the antennas and the arrangement of current-carrying wires, although practical directionality, we now know, was merely an erroneous belief insofar as the azimuthal pattern was concerned and, most likely, a commercially-convenient fib.

The existence, at the upper end of Cefn Du, of a row of 29 (originally 32 – see annotation to **3**) small concrete bases spaced by 4.5m and securing 6" steel tubular masts interpreted, and now supported by definitive evidence, as rear antenna wire tensioners (see **30-33**), was apparently repeated at Oahu, as the diagram of the San Francisco antenna has a row of small dots plotted to the rear (where the rear wires would slope down to those supports – there are no towers depicted at that end). Curiously, this is not repeated for the Japan antenna, which seems to be merely an omission in drawing as it is, apart from being slightly longer, identical to the San Francisco antenna.

Each widthwise pair of masts had a steel suspension 'triatic' wire strung between them, which was insulated from the radiating wires. These could be individually raised and lowered by means of a steel rope attached to a double-handled, hand-operated winch (MS. Marconi. 198). An example of a winch fortuitously appears clearly in the British Pathé newsreel of mast demolition in 1939. The concrete bases to which the winches and a rope-guiding steel loop were attached remain obvious across the site today.

21. H*and-operated, empty, possibly triatic winch uphill of a mast, almost certainly Mast 1, given the concrete anchor to the immediate right of the hammer-wielding gentleman, during demolition in 1939. The scene shows the men splitting mast base flange to tube-securing nuts with a sharp chisel mounted on a thick twisted-wire handle to eliminate impact shock to the user's hand. This usefully explains the numerous split nuts still to be found across the site.* Source: © Reuters via British Pathé, Film ID: 1013.05, issue date: 1/06/1939, under licence.

22. *Winch base and wire-guiding loop (erosion of the underside of the loop apex is evident by touch). The lighter fine concrete at the base of the loop, evident at all winder sites, suggests it was added at a later point to the base. Protruding block 25½" x 7½"(with variations); bolt centres 10" and 11"; bolts ¾" dia, protruding 2½". Lower base typically 85¼" x 37". Lower and upper base apparently cast as one unit. A broken brown stay insulator rests to the rear.*

Antenna detail.

The first antenna at Carnarvon was an ‘inverted-L’ type; it was often described at the time (e.g. by Vyvyan, op.cit. p.61) as a “horizontal, directional type” (but see p.44 for an examination of this assertion). Such an antenna is a ‘bent over’ vertical, monopole antenna, fed against ground. It was bent because the wavelength used was so long – in excess of 17km (10 miles) at the lowest frequency used – as to make the erection of a true, wholly vertical antenna unfeasible; it would need to be over 4km tall for a full, ¼ wave vertical antenna! Thus, a short length of vertical or steeply-sloping wire – from which virtually all the radiation was emitted – was followed by (and connected to) a much longer, horizontal length of wire forming the remainder of the electrical length of the antenna. Later antennas were grounded at the far end, forming a 'half-loop' antenna.

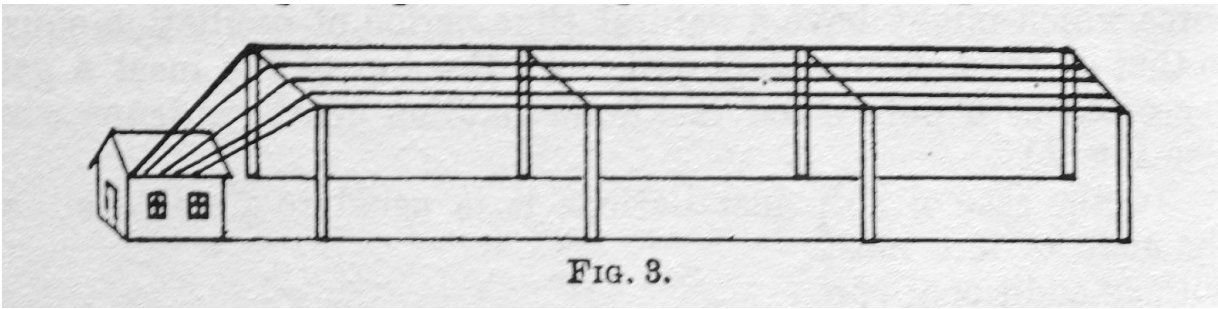


FIG. 3.

23. *The general form of the antenna in use at Carnarvon is shown in Fleming, op.cit, p.238, fig.3.*

A Marconi ‘inverted-L’ antenna, from *Lehrbuch der drahtlosen Telegraphie*, Dr. Ing. Hans Rein (J. Springer, 1917), shows the arrangement of wires for a much shorter antenna than Carnarvon at Hanoi, China very clearly, but has sloping wires to the rear, rather than a blunt termination at height as in **23**). Carnarvon also had rear sloping wires, but they terminated 400’ to the east of the last row of masts, and were individually tensioned, keeping their separation throughout and not converging as they did at Hanoi (*The Wireless World*, July 1914, p.217).

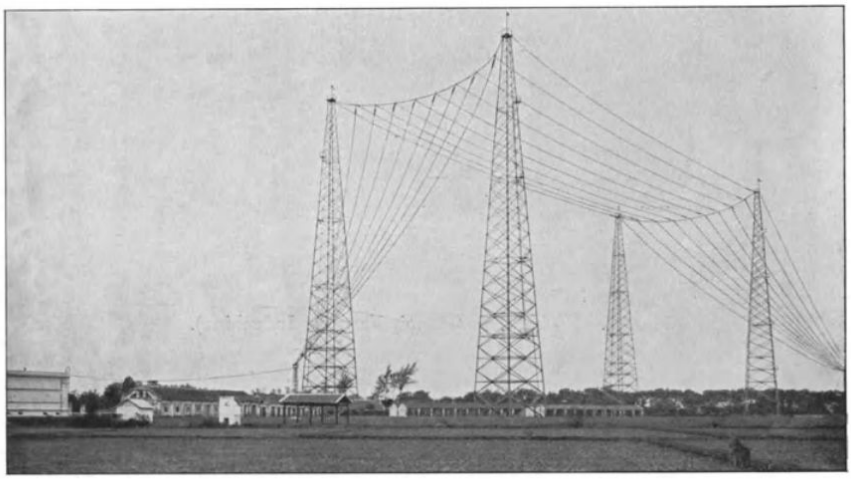
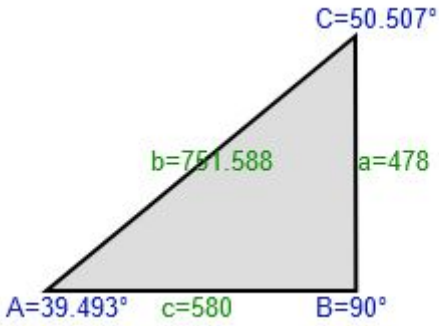


Fig. 84. ⌐-Antenne (Hanoi, Französ. Indochina).

24. *A rare example of a photo clearly showing the wire arrangement in an early antenna, this in Hanoi. Though Carnarvon was much longer than this antenna, the sloping ends during 1914- ca. 1921 were much the same, except that the slopers at the rear terminated 250’ above ground, 400’ from the uppermost masts, and were kept in proper tension by a pole, pulley and weight system (see* **30***).*

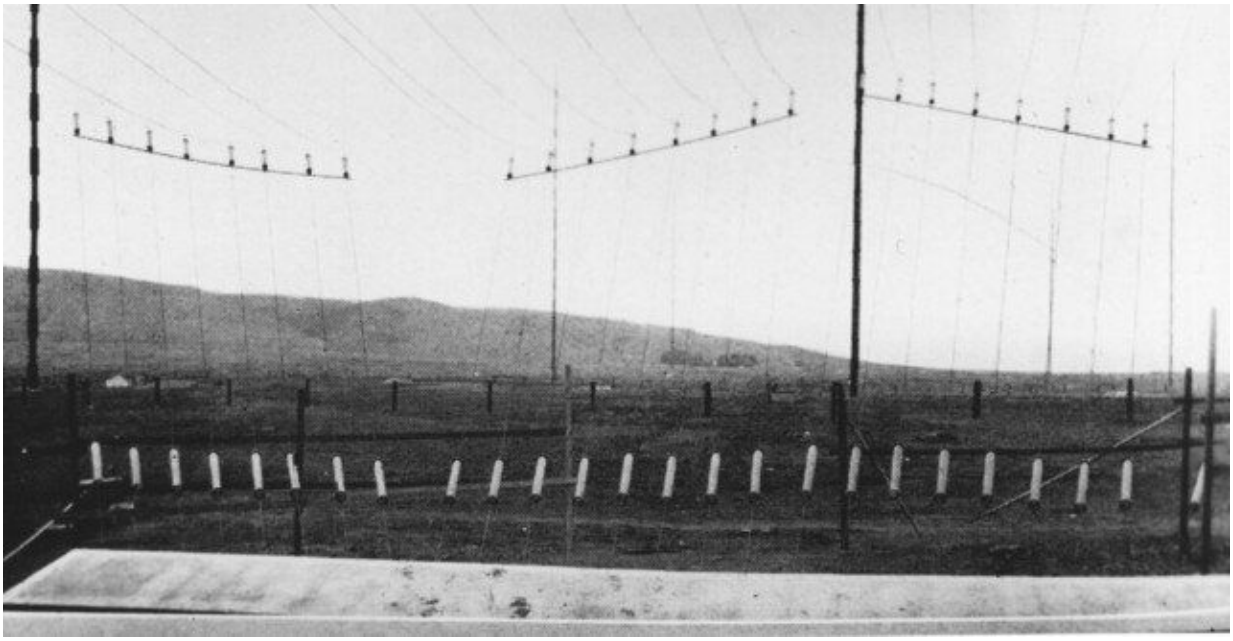
The antenna consisted of parallel and, at the very long wavelengths in use, very closely spaced wires of 7/18 LSG stranded silicon-bronze (Marconi Archive, Bodleian Special Collection MS. Marconi. 198). A reference for LSG wire gauges was not found, but the draft specifications (*The Wireless World*, July 1914 p.215 gives 19 SWG (~1mm, per strand)). The final 7-stranded wire would amount to some 3.2mm in diameter. Photographs are not especially clear as to the number of radiating wires. Contemporary sources initially appear to give conflicting accounts of the number of feed lines, because it changed over time, but the initial number is certain to be 32. *The Wireless World* (December 1913, p.536) gives it as 32 (32 were also used at New Brunswick, for example (Bucher, op.cit. p.292)). A later, September 1919 edition of the same publication gives only 20 wires, but by then, changes were taking place, such as the introduction of an elevated counterpoise and we know for sure that the wire number changed to 20, probably at this time.

A text on the historical development of Carnarvon, written in December 1922 for the '*Engineer*' journal, also gives 20 wires, as does a leaflet about Carnarvon, dated from details within to late 1921 or early 1922, issued by the Marconi Company itself (Marconi archive, Bodleian Special Collections MS.Marconi.198), which repeats much of the earlier, Sept. 1919 *Wireless World* article. The photograph of the transmitter house exterior, taken early in the station's life, seems to show at least 28 wires. There are 29 wire straining pole bases to the rear of the antenna, but 3 were clearly removed to make way for the base of the 1923 double ATI house (see p.75). The wire number was thus 32 in 1914, then reduced to 20 by around 1919 as various modifications were made over time. The number does not seem to have been reduced or increased after 1919, though the material was.

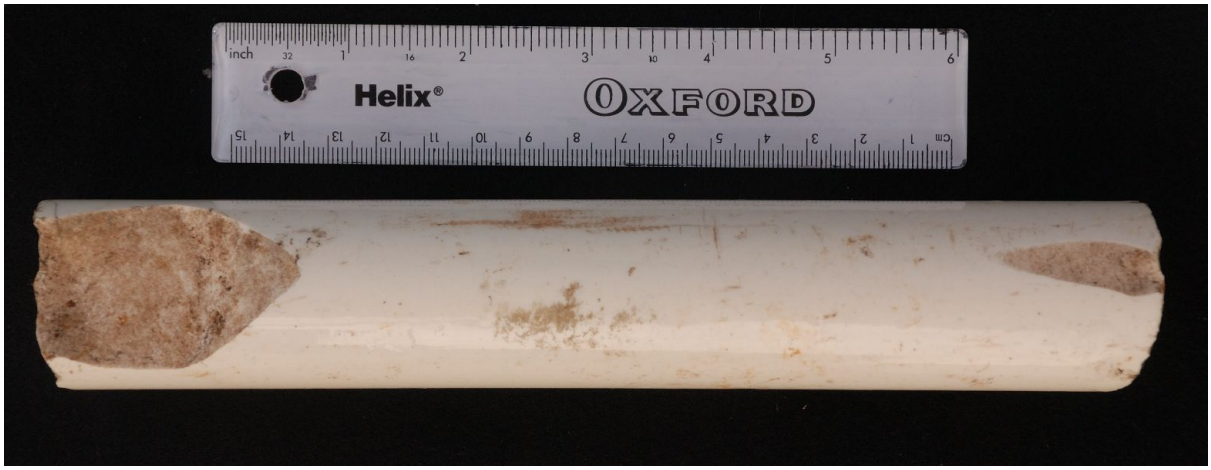


25. *Triangle sides for a tower of 400' (+78' difference in height between first tower base and transmitter house), being 580' from the Tx house, yielding a sloping, vertically polarised-dominant section of about 752', not allowing for sag in the wire. The horizontal section was initially 3.6 times longer than the sloping, at 2685', and later, following extension by ~500'* ca. *1921, 4.8 times longer, at 3585'.*

26. *Carnarvon transmitter house, antenna and ground feedlines, date unknown, but from the debris and ground disturbance, early-on and certainly not later than 1917, as the same image appears in Bucher (op.cit. p.294). The 'telegraph' pole at left feed the two of several fence posts in the right foreground, which have multiple wires, the start of the buried earth screen, running into the ground (cf.***45**). *The sloping radiators are fixed, via rod insulators, to a steel beam fixed on or just behind the retaining dam/wall (see* **40**).



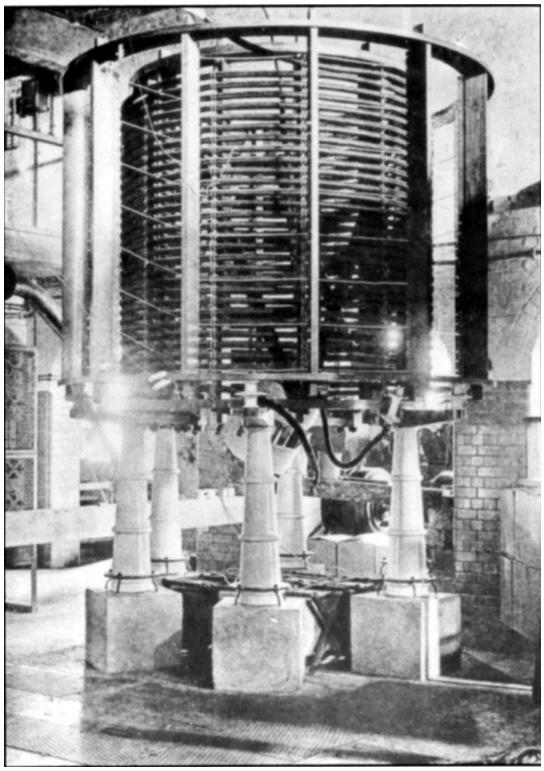
27. *Arrangement of antenna feed wires at Bolinas, California. Note the white ceramic rod insulators and groups of 16 wires on each side of the centreline (32 total). This was somewhat more sophisticated than Carnarvon at the same time; it may be that the radiator connections were strained from the rear of the photo and transmitter hall, as became the installation at Carnarvon after WW1.*



28. *Ceramic rod insulator fragment recovered at Carnarvon. These were used extensively for various purposes around the site. Scale = 150mm/6”*

At ~3800’ (1158m) long, the 1914 antenna approached (at 0.21 wave) a ¼ wave, which is what we would expect; antennas of the ¼ wave type have always been known as ‘Marconi’ antennas, and represents a monopole where the ground or ground screen/counterpoise represents the ‘missing half’ of the antenna.

The frequency used at Carnarvon quickly moved to 11,100m, where the antenna would be 1/10th wave. Resonating of the antennas at longer wavelengths than their natural wavelength was achieved, then as now, by the use of substantial inductor coils (see **29**). The antenna was later used at 14,000m wavelength, where it would represent close to 1/12 wave.



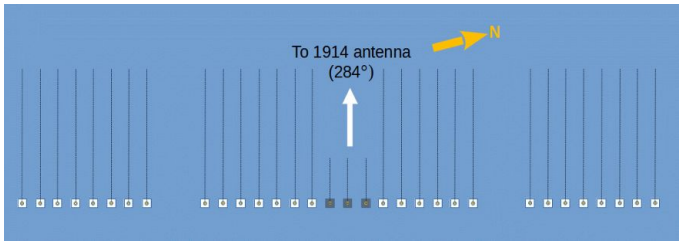
29. *One of the matching (‘tuning’) inductors in Carnarvon’s transmitter house. These could be tapped at various points, according to the wavelength in use. Bodleian Special Collection MS.Marconi.198. Date uncertain, but likely between 1918 and 1921.*

A row of 29, 3’ x 3’ concrete bases, originally numbering 32, in which iron tubes are set, lie to the rear of the original 1914 antenna – external diameter 6”, wall thickness of ½”, inserted ~ 13” into concrete. They are all separated by 4.5m, but with separated groupings. These are centred on, and aligned with, the 1914 antenna, the middle point of which later, from 1923, featured a substantial inductor building (see **72**). Counting from the northern and southern extremities of the antenna wires, between bases 8 and 9 for each section, there is a gap of about 64 feet, which is half-way between the upper, outer masts and the central mast. There is, today, another gap of, coincidentally, the same width, lying immediately behind the central rear mast. It seems certain that three strainer bases, which would fit precisely in this gap, were removed in late 1922 or very early 1923 to make way for the double ATI, hence there only being 29 bases now evident. The built pattern was an 8-16-8 grouping of strainers, with a 64-foot gap between each of the 8 outer strainers and the inner 16. This reflects the general grouping and separation of the horizontal antenna wires, which were at that point kept at equidistant spacing all the way to the rear by the tensioners.

The row of poles, of which no photograph at Carnarvon is known, was for rear antenna wire tensioning, using a system of coaxial weights running (slightly) up and down a column *via* a top pulley. This arrangement is confirmed as present from the outset, being mentioned in *The Wireless World* (‘*Trans-Ocean Wireless Telegraphy, New Transatlantic Service, the English* [sic] *station described’*, July 1914, p.217) as follows:

> “*Even tension is kept in every wire by means of a balance weight, thus minimising the possibility of breakage of wire due to wind pressure*”.

The bases for the poles are seen to be present in 1923 photographs of constructing the double ATI for the second extension, but the poles themselves are not. The earlier, 1921 extension masts, which lay 300 feet to the east of the row were substantial (60 feet on a side at the base) and self-supporting. But, if there was still believed to be the need to individually tension the radiating wires, this would still require the straining poles, or something similar to them. No replacement tensioner row is seen to the east of the two massive pylons built for the *ca*.1921 extension. It is possible that the tension could have been effected by the wires running ‘backwards’, from the new towers to the original, 1914 row. This would only require the top pulleys, or the poles themselves, to be rotated by 180 degrees, to face the towers. A slack wire seen at far right in **72** may be evidence that the pylons were still in place in early 1923. A further rod-insulated wire may also run in the same direction, suggesting that the tensioners had, until then, been reused in the forwards-acting manner for the 1921 extension. No pole-and-weight tensioners were used for any part of the 1923 extension to the antenna, as the rearward wires converged on the double ATI strainers (see **76**).



***29a**, left: rear dynamic antenna wire tensioning pillar arrangement for the first antenna. The three grey pillar bases were removed to make way for the double ATI house, but the whole system of strainers was redundant from at least this time on.*

The 6” base tubes had a collar a few inches above the base, of 6½” external diameter, that secured, possibly by screw attachment, a narrower tube of 4” external diameter. Accounts in *The Marconigraph* tell of 32 wire elements to the 1914 antenna. There are two additional but inexplicably orphaned strainer bases found 200’ to the west of the row, near the northern limit. The collar at the bottom of each tube may have allowed the poles to be removed and refitted, as required.

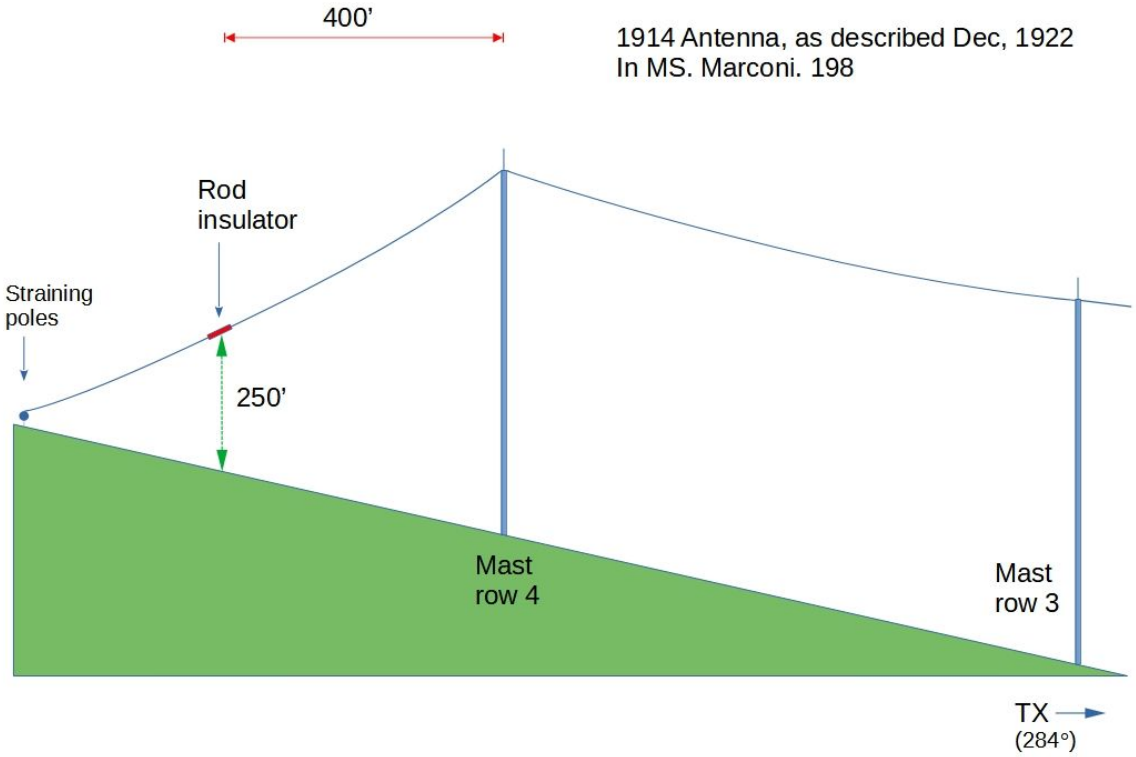
30. *A poor copy image from* The Wireless World*, May 1914 (p.95, image 7 of a montage of 8), showing a row of wire tensioners at the Marconi, New Brunswick station, USA. Note pulleys at top, facing the antenna (off scene, to right), and coaxial weights near their bases. Height of the bases, taking the man to be an approximate guide, is about 22 feet. Chains attached to the bottom of the poles (just visible to the left of the ladder base, and still to be found at Marion and one base at Carnarvon) are of unknown function at the time of writing, but possibly for limiting the upwards extent of the weights' movement. See also* **31-34**.

31. *Concrete base, showing the remains of a 6" OD lower steel tube, part of a straining system for each of the antenna wires. Base is 3' x 3'.*

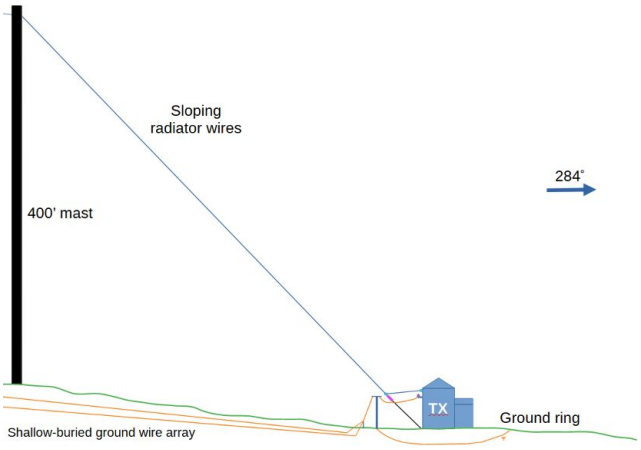
32. *Iron tube base at Carnarvon, showing attachment point, shackle and chain, which is also seen at Marion (see **33**). Chain appears more substantial at Carnarvon, and no trace of an attachment on the base block was found on any such base.* 53.122130°, -4.176786°. Trowel blade = 6”/150mm.

The same base-and-tube structures are seen at the remains of Marion, MA, USA, which also have tubes with an attachment point, in this case, with a light chain, possibly to arrest excessive upward movement of the straining weight, running to a loop in the base side via a ‘D’-ring, which may or may not have been attached to the tube base. At Carnarvon, the attachment point on all remaining 29 tubes was immersed almost by half, to the level of the hole, in concrete, whilst it was well-clear in the Marion example. Late in this project a single example of a collared and chained tube was discovered (**32**, above) to the west of the row of 29 tubes; a further non-collared and unchained example lay some 9 yards to the east of this.

33. *Wire strainer base at Marion, MA. Image by kind permission and © of Marian Howell via Sippican Lands Trust.*



34. *Simplified schematic of antenna as <u>described</u> at the end of 1922, but of the antenna as it was <u>built</u> in 1914. The radiating wires were (by ca. 1921) 20 in number, with ceramic rod insulators isolating them from the rear straining wires that ran to pulleys on poles with coaxial weights (see* **30***). This arrangement, though with 32 wires, was in place for the original, 1914 antenna. It is unclear as to whether the straining poles were in use after 1921, when a ~500’ extension to the east may have made them redundant; they could still have been used through a forwards (westwards) acting turn of the pulleys to face the rear. Slack wires and rod insulators are seen in the double ATI image (see* **72***) emerging into shot from the uphill direction of the pylons, which may hint that the strainers could have been used up until 1923. Forward strainers above the transmitter house, however, appear from around 1921 onwards (see* **56***), so the straining arrangements at the rear could either have been used in addition to those to the front, or else discontinued; the situation is not clear. Use of straining poles was discontinued at 1923 extension. No pole strainers were used at either end of the 1923 array wires (of which there were 12).*



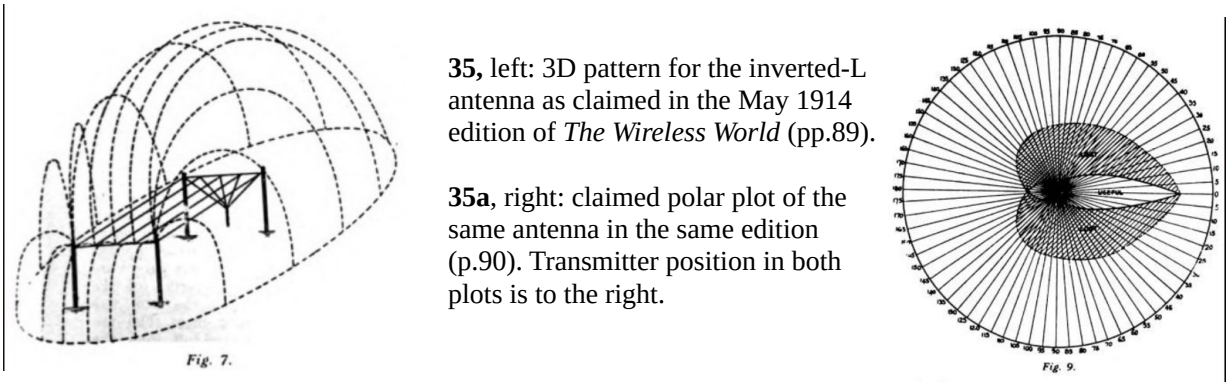
34a. *Schematic of antenna and RF ground feeds at the front (western end) of the antenna during the 1914 to ca. 1921 period.*

A Directional Antenna?

The directionality of early Marconi inverted-L antennas was, at the time, a topic of intense academic debate, even featuring in a 1913 Parliamentary Select Committee hearing. In a post submitted to the amateur radio forum on *QRZ.com* as part of research for this report, it was universally agreed that, through experience, computer modelling and historical information, the 1914 antenna at Carnarvon, aligned to the WNW with a great circle (True) path of 284 degrees could not have displayed meaningful directivity of the nature put forward by Marconi. It would, rather, be omnidirectional in its azimuthal pattern.

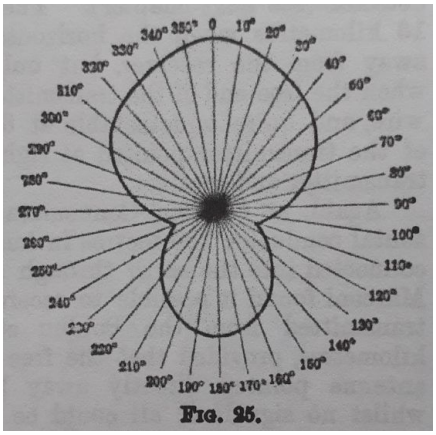
Marconi and others undertook measurements and plotted-out their results to demonstrate this directivity. But it was noted by Fleming (op.cit, p.182), who claimed to have confirmed Marconi's findings, that "German writers" did not accept the antenna was directional. Germans engineers had more experience of their antennas as, unlike in the UK, there had been no long delays in erecting a wireless network. This confirms the view put forward by Swedish amateur radio operator, SM0AOM, Mr. Karl-Arne Markström, who was Senior Systems Engineer at the Head Office of Swedish Telecom Radio, the Government organisation which owned and operated the Grimeton SAQ VLF site between 1924 and 2003, in an online discussion on this matter, that the claimed directionality of antennas was the topic of fierce debate at the time. Mr. Markström commented:

> *"The 'inner workings' of antennas in general were intensely debated during the early 1900s, and it took until the late 20s/early 30s before theorists like Hallén, RWP King and Schelkunoff presented more developed theoretical foundations for how directional antennas actually worked.*
>
> *The distinctions between 'near field' and 'far field' directive patterns were not fully worked out. Directivity seemed to be different between 'close' and 'far' ranges, which was a subject of quite deep 'learned disputes'.* [The disappearance of the claimed directivity at 'very large distances' is mentioned by Fleming (op.cit., p.182), but without contemplation of why that was so – **JR**]
>
> *There were at least two 'schools of thought' one based on the early works of Hertz, Max Abraham, Zenneck and Sommerfeld, which gained followers such as Hallén. Other views came from C S Franklin and Fleming and they were not always compatible.*
>
> *Hallén was before my time, but one of my professors at Uni was a disciple of him, and told about how fierce some of the "learned battles" had been.*
>
> *To get any marked directional patterns from an antenna, it either has to be large compared to the wavelength, or be built as a phased array. The travelling-wave or Beverage receiving antenna may be seen as an exception, as it relies on the differences in wave velocities between space and ground to achieve its directivity."*



35, left: 3D pattern for the inverted-L antenna as claimed in the May 1914 edition of *The Wireless World* (pp.89).

35a, right: claimed polar plot of the same antenna in the same edition (p.90). Transmitter position in both plots is to the right.



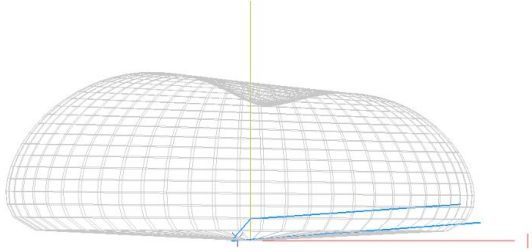
35b: *Polar plot, claiming a significant degree of azimuthal directionality measured by Marconi that is much more akin to a 2-element beam antenna than an inverted-L. His methodology is not fully known. Fleming (op.cit, figure 25, p.183). Modelling in 2024 by Michael G. Mladejovsky, Ph.D. (electronics engineering, University of Utah), WA7ARK, showed that Fleming's and Marconi's results with small, very low (1.5m above ground), lossy antenna test systems were correct. But modelling of full-sized commercial inverted-L Marconi antennas shows purely omnidirectional radiation.*

It is important to note, when considering Ambrose Fleming's claims, that he had, since 1899, been a paid scientific advisor to the Marconi company. The magician and amateur radio enthusiast, Nevil Maskelyne, who 'hacked' a demonstration being given by Fleming at the Royal Institution in 1903, clearly held that Fleming's position at Marconi had compromised his scientific integrity. The *Electrical Review* (N°. 1334, June 19, 1903) agreed, making the cutting editorial comment:

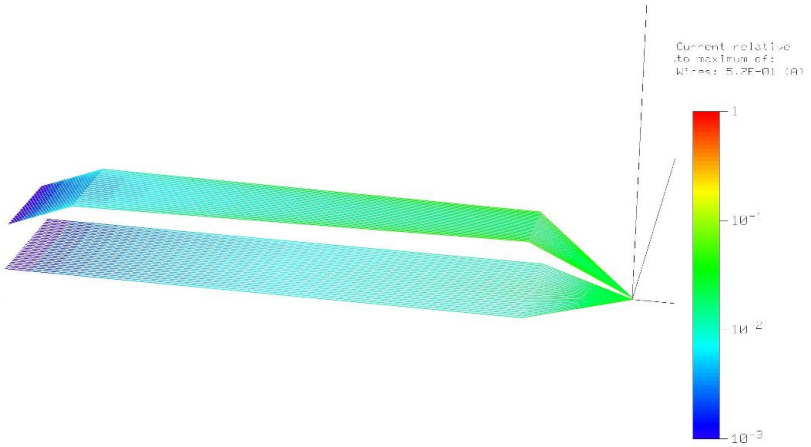
> 'When the philosopher stoops to commerce he must accept the conditions of commerce.'

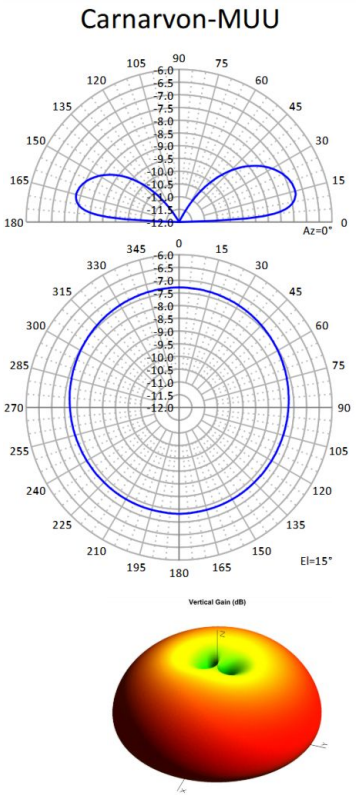
Maskelyne's stunt was designed specifically to disprove, with an entirely *un*tuned transmitter, Marconi's claim that tuned ('syntonic') wireless systems – that only his company then supplied – provided transmissions that others could not interfere with. There was also the associated implication that such systems provided secure communications. Both these claims were absurd, which Marconi clearly would have known to be the case. But, as always, there were strong business interests to promote through showmanship. Fleming undermined his own credibility in a series of letter exchanges about the 'hack' with Maskelyne in *The Times*, and interviews by *The Daily Telegraph* and *The Electrical Review* over an extended period. Fleming's reputation was damaged to the point that his contract with Marconi was not renewed when it expired shortly thereafter, in December, 1903. A full account of the Maskelyne hack is given in *Wireless: from Marconi's black-box to the audion*, Sungook Hong, The MIT Press, 2001, chapter 4, pp. 89-118.

The inverted-L antenna, as similar as possible physically and electrically to Carnarvon, was modelled by former Radio Hoyer (Curaçao) radio technician and radio historian, Dr. Fred M. Chumaceiro. Using state-of-the-art, Lawrence Livermore National Laboratory, NEC-5 software with a long heritage extending back to the 1970s, set to a frequency of 21kHz, the output shows the antenna is, to within 0.7dB, entirely omnidirectional in azimuth. Computed antenna capacitance of 0.034μF and self-resonance of 55.55 kHz (5,401.8 m) is in excellent agreement with the 55.0kHz (5,400 m) and 0.038 μF cited in relation to the real, 1914 antenna within Marconi.MS.198.



Simple MMANA-GAL model of the 1914 antenna, revealing an omnidirectional pattern. Side view from south.





36, *above: radiating and ground wire computer model of Carnarvon's first (1914-built) antenna, created within NEC-5 software, showing currents within each wire. Most of the current and thus the radiation emerges in the sloping front (western, to right) section.*

36a, *right: elevation (top panel) and azimuth (bottom panel) radiation patterns and gain figures for the 1914 antenna. The antenna had -7.29dBi gain at the TX (western) end, being omnidirectional to within a trivial 0.53dB. Ground = 1 mS/m (see **40a**), dielectric constant = 10. Antenna resistance (inductor included) = 2.1Ω. Output is found to be much the same for much simpler models in less capable software; this is not a complex antenna to understand!*

36c*: 3D rendition of radiation pattern (western, transmitter end in x-axis direction (front)).*

The computed gain of the antenna, relative to an isotropic radiator, is minus 7.29dBi. The addition of a ground screen, as we are told was undertaken at Carnarvon from the outset, would improve the efficiency. An elevated ground screen (i.e. a counterpoise), as later installed, improved things even further. The efficiency of the Marconi inverted-L was stated by Elmer Eustice Bucher as being 2.21% (*Technical Description of The Alexanderson System for Radio Telegraph and Radio Telephone Transmission*, 1920, Wireless Press, NY, p.43). At higher frequencies, such as the 52kHz used at night at Carnarvon, the efficiency would be higher.

Marconi's radio installations were strategically-important communications advancements at a time of rampant, competing imperialism, especially between the UK and Germany. The development of radio sparked political concerns over monopolisation and control in a number of countries, including within the British colonies themselves, notably Canada and Australia. Marconi had competitors, most notably the German company, Telefunken.

Anything that showed a greater effectiveness of Marconi's system over the competitors' were critical to business success, which was by no means assured for the company at that time. Government customers for the use of Marconi's systems (his business model was to effectively lease equipment and operators), including Britain, did not automatically accept the company's claims to superiority, conducting their own assessments of performance. So crucial were even the slightest differences in performance that Marconi himself, in his Evidence in Chief to the Select Committee on the Marconi Agreement (Parliamentary Archives document LG/C/24/2/14, p.14), felt he had to correct a distance measurement between San Francisco and Honolulu, asserted by Mr. Beach Thompson, a critic of Marconi's, as being 2,400 miles was, in fact, after having had it "carefully measured" (correctly, the 'geographical miles' in question being essentially equivalent to the nautical mile) only "2,078 geographical miles" – a trivial difference, but one that Marconi believed mattered in considerations of competing wireless systems.

Antenna directionality was one consideration in an April, 1913 report to the Post Master General that – urgently, given the growing shadow of war – considered which of the competing systems would be most capable of providing continuous, reliable, long distance communication across the Empire (*Wireless World* account of the report, June 1913, point 16, p.159).

A year earlier, a major political controversy, dubbed 'The Marconi Scandal' had developed, involving allegations of 'insider trading' by Government ministers – including Lloyd George – in American Marconi shares as they decided who would construct the wireless system. The Post Master General – Herbert Samuel – was one of those against whom allegations were made. A directional antenna would put Marconi ahead of his competitors and would, on its own, have been a strong reason to choose his system over another. Marconi dwells on the antenna, including a diagram, for some time in his submission to the Select Committee on the Marconi Agreement (op.cit., pp.3-4).

The politicians, for their part, may well have been seeking any superficially reasonable justifications for a choice that would further enhance their personal wealth, although after a protracted series of Parliamentary investigations, reports and a criminal libel case, the politicians were found, perhaps inevitably, to have acted in good faith.

This labyrinthine and, today, largely forgotten, years-long episode in Marconi and UK political history, that profoundly damaged the public's views of politicians, is covered in depth, and freely available online, in the April 1978, Ph.D. thesis of Kenneth Lunn, M.A. - *The Marconi Scandal and Related Aspects of British Anti-Semitism, 1911-1914,* University of Sheffield, Dept. of Economic and Social History. Raboy (op.cit., pp.366-379) devotes a chapter to the scandal.

Whilst Marconi may have sincerely believed his antennas were directional, backed-up by his 1906 experiments and politicians technically incapable of realistically challenging his claims, by the time the Select Committee inquiry came around, even if he had subsequently realised his error, he had powerful and fundamental business reasons not to say very much, or even to maintain the claim. The politicians had, by 1913, made a net loss on their investments (Lunn, op.cit., p.9; also *Seren Cymru*, 4/4/1913, p.8).

During this study, key evidence that may partly explain the claimed directionality came from the discovery of the use, discussed in Fleming (op.cit., p.184-186), of long (up to 230m) and very low (6ft/2m) to the ground antennas, used mostly for receiving but also, in fewer cases, for transmitting tests. Fleming further notes (ibid., p.186) that, as he brought the end of a low receiving inverted-L closed to the ground, the directionality became more pronounced. At the time, Marconi was trying to create a 'mastless' antenna (Evidence in Chief to the Select Committee on the Marconi Agreement, op.cit., p.3), where wires could simply be laid on or very near to ground. This was because masts dominated the expense of installing wireless stations.

These very low antennas would have exhibited modest properties of a Beverage antenna, invented by Harold H. Beverage and who was granted a patent on the design (patent US1381089A, 7th June, 1921). Briefly, the antenna is a long, 'travelling wave' type, which provides for uni- or bi-directional properties, depending on whether or not one end is terminated with a resistor. The antenna also very considerably improves the signal-to-noise ratio – a useful property when the receivers were fairly insensitive. The Beverage can only be used for receiving, although Marconi tried to use them – successful only for very short distances – for transmitting. Marconi and Fleming assessed directionality of their transmitting antennas by the signal strength in their receiving

antennas. The Beverage antenna and its properties were not known until many years after these measurements were made.

A simple test for this study (02/08/22) using RTÉ 1 at 252kHz from a single transmitter at Clarkstown, Co. Meath, Ireland, and a 40m-long receive antenna laid about 15cm above ground showed a marked enhancement of at least 6dB (a power factor of four) in signal strength when the wire pointed towards the transmitter (at a distance of 156km), compared to when it was broadside (at 90 degrees) to it. Even at extremely short wire-to-wavelength ratios – in this case, just 1/297th wave – the directionality of a very low antenna is quite strong. Marconi's receive antennas had a wire:wavelength ratio of up to 1/24th wave; the directional properties increase with greater wire length. The Clarkstown long wave transmitter subsequently closed down in April, 2023.

Marconi and others were, in producing their plots, sometimes measuring the characteristics of their *receiving* antennas, and not those of the transmitting antennas. However, modelling does show that the 1906 tests by Marconi *did* yield directional transmitting patterns, but that these did not translate into the same effect in the far field with full-sized commercial antennas. No commercial 'mastless' stations with close-to-ground wires were ever built by Marconi's and there is no doubt they would have jumped at the opportunity to make the substantial savings in station build costs, had this directionality with low antennas actually been available to them. The ability to to use low antennas for receiving but their uselessness for transmitting was, interestingly, clearly recognised at least as early as 1912, when an article entitled "The Bent Antenna" discussed this in *The Marconigraph* (Vol. 11, Number 19, October 1912, p.282).

The erection of the 1923 extension, albeit of different type and radiation pattern, at an angle to the 1914 antenna of 130 degrees to the north-east must mean that Marconi and his contemporaries had by then, if only quietly, realised their much-repeated, earlier claims of directionality for the inverted-L antenna were wrong. Bucher explicitly stated that the directionality "disappeared at distances beyond 300 miles or so from the transmitter and thus the benefits of the directional radiation are not realised" (*The Wireless Age*, Vol. 7, No. 11, August 1920). In other words, there was *no* inherent directionality to the antenna.

It may seem surprising to us that Marconi, celebrated then, as now, as the 'inventor of radio', could make such errors. But, as he himself remarked, Marconi was "not a professed scientist" and, some years earlier, had advocated the idea that 'his' waves were different from 'Hertzian' (electromagnetic) waves *(H.J.W. Dam, Strand Magazine, Vol. XIII:35, March 1897, p.276)*. His close colleague and employee, Charles Franklin, following Marconi's death, criticised him in a very particular and revealing way, cited in *Raboy, op.cit.*, p.673:

> "His scientific knowledge was weak, his engineering knowledge was weak, but he had a damned lot of intuition and common sense. He may have initiated the beam system but he didn't know a thing about it"

In his 1999 book, which devotes just seven pages to Carnarvon, most of that being a light reworking of Fleming's 1933 work, Hari Williams – very surprisingly for a man with professional electrical engineering qualifications – repeated, without question, the directionality of an inverted-L antenna (*Marconi and His Wireless Stations in Wales, Gwasg Carreg Gwalch, 1999, p.71).* By then, it had been clear – for 79 years, as Bucher's comments of 1920 show – that this was not the case.

It was disappointing to discover that the directional claim is repeated in a Gwynedd Archaeological Trust report 1032, *First World War Military Sites: Manufacturing and Research and Development*, March 2015, Kenney, Flook and Daimond; such is the impact of the Williams text. Williams went so far as to introduce a further claim, in that he ascribes the 1918 Wales-Australia contact to the Carnarvon antenna having "dual directional properties", i.e. directionality both to the west and east (the latter in the reverse to its intended operation, to the United States). Not even Marconi appears to have made this "dual directional" claim which, had he done so, would have entirely contradicted his widely-repeated assertions about the antenna at the time. Williams' claim is wholly spurious. Ironically, the second phase (1923) of extension to the first antenna and its later (1925) split-off extension, N$^{o.}$2 antenna, were of a 'half-loop' design and modelled to have had a fairly weak 'figure-of-eight', though at the cost of diminished maximum gain and weak nulls in the widthwise direction (which would have been to the US, it's primary destination, in the case of the 1923, N$^{o.}$2 antenna).

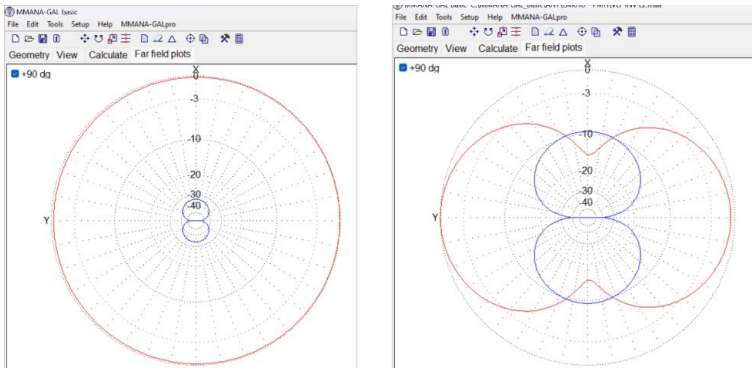
Crucially, an article appearing in the September 1912 edition of *The Wireless World* (pp.214-216) gives the draft specification for the Imperial Scheme contract, which shows there was no expectation of 'dual directionality' for the inverted-L:

> "where a station is required to communicate in more than one direction, separate transmitting circuits to be provided"

The example of Marconi's Kahaku station would appear to clear-up any confusion as to the meaning of the term "transmitting circuits" – two antennas, for communicating with California and Japan, were installed.

In any event, the inverted-L was, as we have considered in depth, not directional to the front, rear, or any other point; it was omnidirectional, save for any slight change to the pattern that may have been afforded by different ground conditions, ground reflections and the sea horizon to the SW-NW at Carnarvon. The later antennas, of half-loop design, had a modified pattern with weak bi-directivity, but these have never been considered in any past Carnarvon texts.

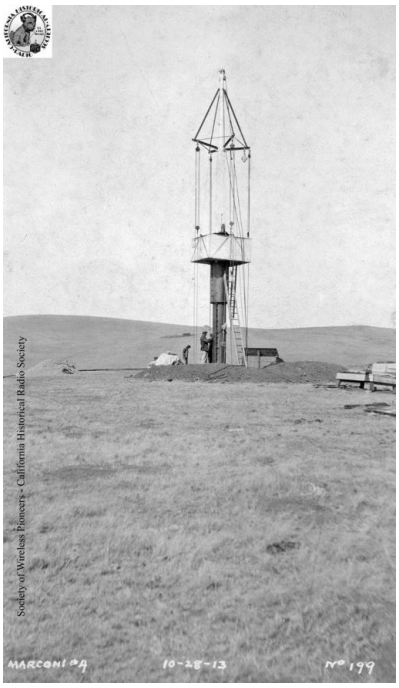
The first antenna, horizontal of about 3837' (1173m) total antenna length, equal to 4692m wavelength, was a broadly ¼-wave antenna. Carnarvon is known to have used 5000m wavelength initially (tests with Coltano, Italy), which can therefore be deemed to have been the approximate design wavelength; the September, 1919 edition of *The Wireless World* (p.301) asserts the 1914 antenna had a "natural frequency of 5600m", whilst a *ca.* 1922 Marconi Co. pamphlet (MS.Marconi.198) gives 5800m (the antenna had been extended by ~500' by then).



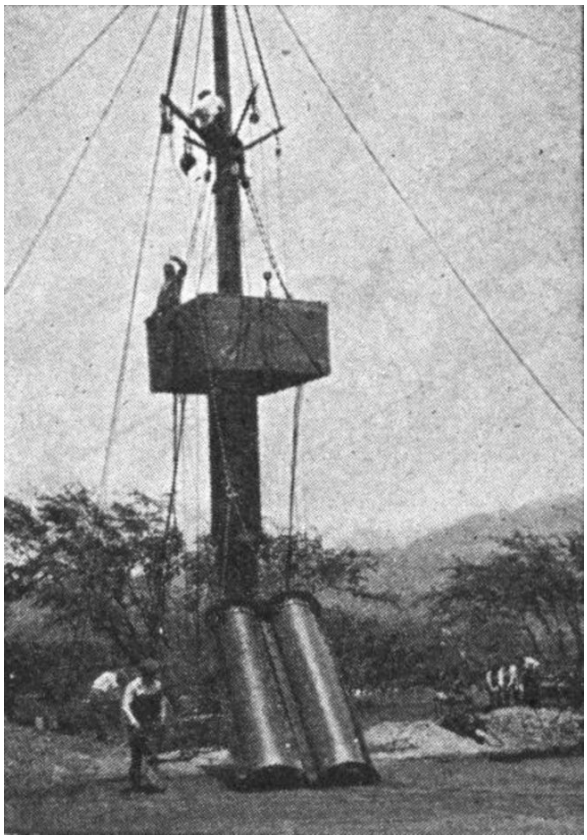
36c. *Left panel, azimuth model of the unmodified 1914 antenna, showing almost purely vertically-polarised, omnidirectional radiation.* ***Right panel****, azimuth model of the modified antenna from 1924 onwards. The antenna form was then of a 'half-loop', creating a weak directivity, though of lower peak gain than the inverted-L and with weak nulls at the 'waist'. For both the later antennas, the latter pattern applied and was less than ideal, certainly for the upper (now MUU, later GMU) array in terms of its intended receiver in the US. Courtesy Paul M. Hawkins, former submarine communications antenna design engineer.*

Erecting Masts

Erection of the masts utilised a rising platform, located in a square guiding socket formed by diaphragm plates between the tube sections (Bucher, op.cit., pp.299-300; see possible plate remains at **39**). Photographs of installation are not known from Carnarvon, but are available from contemporary, similar Marconi installations in the United States, in this case of a smaller diameter mast using half, rather than quarter sections.



37. Early stage of mast erection, showing the rising platform, at Bolinas, California. Image courtesy California Historical Radio Society.



38. *Rising mast construction platform, showing two sectional tubes, in this case for an unidentified station of smaller lower diameter masts than at Carnarvon. Bucher, op.cit, p.300, figure 312.*

39. *One half of a heavy steel plate with outer and inner bolt holes and a square central section. It's role is uncertain, but the inner bolt holes may indicate a square-section element was attached within and almost certainly relates to one of the 1914 masts; the description of diaphragm plates between mast tube sections, for the purpose of guiding the rising erecting platform, matches this plate; if it was indeed such a plate, the square opening was probably sufficient for a man to pass through for access up the mast. Diameter = 39.25"; central square of sides 14.5"; hole diameters 1.75". Further understanding is sought.* 53.122331°, -4.174260°.

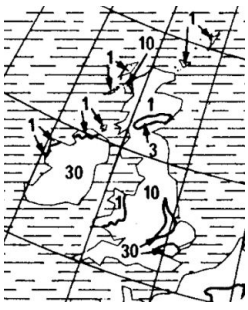
During 1921 or slightly earlier, the earth screen buried 6" deep in ground under the antenna was changed to an elevated screen, more properly known as a counterpoise. This system would later service extensions to the antenna system. We now turn our attention to those grounding systems.

Radio Frequency Grounding.

As we have seen, the underlying form of the early antenna at Carnarvon was a vertical monopole, but bent over. The ground provides the ‘missing half’ of the antenna, where the return current flows. But the ground beneath an antenna causes large losses due to its poor conductivity. The presence of moisture, bodies of water (especially seawater) or mineralised ground improves the conductivity to varying degrees. But, on land, conductivity is rarely good and the losses are exacerbated at VLF frequencies, which readily penetrate several tens of metres and more into the ground. The conditions can be improved by providing a conductive layer of wire either slightly under, lying on or, better still, elevated above the ground beneath the radiating antenna wires. Wires in or on the ground are termed screens, whilst elevated wires are counterpoises, though “screen” was generally used for both at the time.

Bucher (op.cit., p.305), drawing on a January 1914 *Wireless World* article (‘Grounding Systems for High Power Stations’, p.610) provides a very clear, generalised diagram of how a typical Marconi station was earthed at radio frequency (see **44**). Bucher adds that slightly different arrangements might be used where stations were located on rocky or otherwise difficult ground; then, the ground system wires would simply be laid out on or very near the surface. Carnarvon’s transmitter buildings and immediate surroundings are on rocky ground, with a varying depth of boggy peat, overrun with water after heavy rain in any season. At the time, it was held to have good ground characteristics. Ground movement and water flow at the site was such that, at the eastern end of the transmitter building, facing the antenna, a fairly substantial concrete retaining wall, more akin to a deflecting 'dam', was built along the entire frontage, with a deep drainage ditch between it and the building.

40. *A low but substantial concrete retaining wall/dam (centre left) and deep drainage ditch (centre) in front of the station transmitter buildings. The site is extremely boggy and wet in all seasons, and is susceptible to soil movement. The boggy layer impedes the penetration of VLF waves into the acid igneous bedrock below, but the overall characteristics of the ground would nevertheless remain quite poor; the ITU global ground conductivity atlas maps (Recommendation ITU-R P.832-2, 1999, p.10) gives a low-resolution assessment of Wales’ ground conductivity (**40a**) as a poor, 1 mS/m; seasonal changes at VLF are insignificant (ibid. 3.1, p.2).*

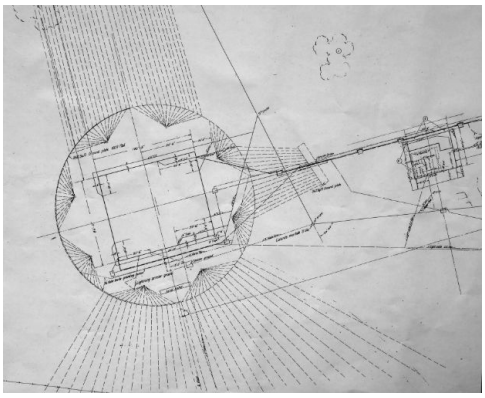


40a

According to page 4 of the 7th December, 1922 Marconi archive document '*The Marconi Transatlantic Service, Carnarvon and Towyn Stations, Historical Description'*, noted as written for '*Engineering'* (journal or magazine – exact publication currently unknown) the earth wires were buried at about 6" (Oxford Bodleian Special Collections, MS.Marconi 198).

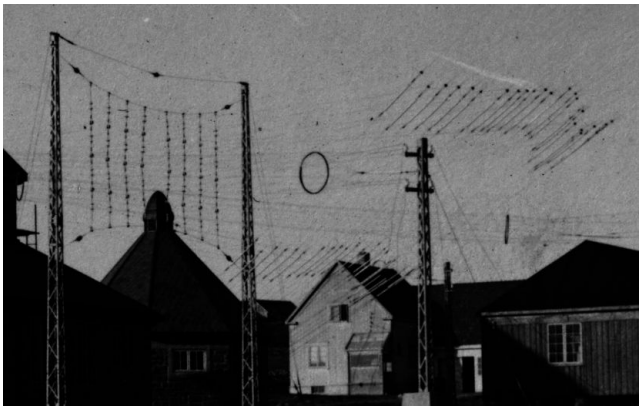
During fieldwork at the station transmitter buildings, by kind consent of the present owners, earth wires of 6-stranded copper, 3mm total diameter, were readily found at the margins of roughly circular, sloping ground that, with the edge of the slope being at the 100 foot radius, centred on the middle of the buildings (as given in the 7/12/1922 Bodleian document) almost certainly defined the first earth screen perimeter, towards the NNW of the transmitter buildings. Due to very boggy, mobile ground and vegetation, it is very difficult to look for evidence of any outer earth ring such as depicted generically by Bucher (see **44, 45**). The existence at Carnarvon of the second ring of greater radius is mentioned, however, both in *The Wireless World*, December 1913 (p.536) and in the later, July 1914 edition (p.217), though repetition of earlier works was common at this time, and cannot necessarily be taken to indicate accuracy. An outer ring is considered possible but presently unconfirmed. On the other hand, the lack of such an outer ring at Bolinas, a contemporary of Carnarvon, might suggest the latter also never had one.

41. *An iron peg, hook or handle, with stranded copper wire apparently firmly attached to it and seemingly leading away from the buildings, to the north, was found along a line that may have been that of the inner earth screen perimeter (diameter of ~100 feet). An iron/zinc earthing plate may well be buried beneath. Trowel blade = 6"/150mm long.* Approx. 53.124134°, -4.193616°.



42 (left), **42a** (above)

42. *The pattern of the earth screen at Bolinas is seen very clearly, running lower centre to centre left, in an aerial photograph of 1913/14 (based on date of construction and opening given by Bolinas Museum, CA), taken shortly after installation where the bright cut ground for the wires contrasts strongly with the surrounding grassy cover. Survey at Carnarvon shows the extent of its buried screen was the same – to just inside the outer anchor blocks of each mast.* **42a.** *Station grounding at Bolinas, where there were 32 ground wires under the antenna (upper left) but only one ring and the same may have been true at Carnarvon. Images courtesy California Historical Radio society*



43 (left). *Looking away from the transmitter building at Stavanger Norway – a close contemporary analogue of Carnarvon. As for Bolinas, CA, narrow trench scars for the buried earth screen are seen running towards the antenna masts. Here, incidentally, 24 feeds are clearly seen, thanks to the obvious white ceramic rod insulators (lower edge of photo). Carnarvon had 32 radiators initially, reduced to 20 later on. The multiply-insulated wires between the foreground lattice towers carried (3 x 8 =24) radiator connections from the transmitter hall to the sloping radiators just in front of them which themselves are mechanically connected via insulators to the ground slightly behind the towers; all is confirmed in the highest quality, contrast-enhanced scan (***43a***, **right***) of Bodleian Special Collections MS.Photogr.c.249, photo NN290 (this is a duplicate number in the original album).*

It is boggy and, after rain, wet to the point of inundation across large areas beneath the 1914 antenna. These were superficially good ground conditions that were deliberately sought to encompass the whole antenna system or, if that was not possible, at least the area around the transmitter house. There was an interesting belief at the time that such watery environments would "afford a direct electrical connection to the Ocean" (*The Marconigraph* Vol. II, No. 19, September 1913, p.415). Whilst that notion was fanciful, the expectation of the effectiveness of wet ground and the sea in improving antenna performance was entirely correct. What was not appreciated was the skin depth at VLF frequencies and the two-layer vertical structure of the ground at Carnarvon; an upper, fairly shallow layer of waterlogged peat with igneous felsic tuff lying beneath. These factors probably meant that the ground was substantially poorer than the surface suggested.

Fleming (op.cit., p.276) says of Carnarvon in the early years: "The earth-plate is a very extensive system of copper plates buried in the earth." If Fleming was correct about this, the earth system must have been of the form detailed by Bucher (op.cit. p.305):

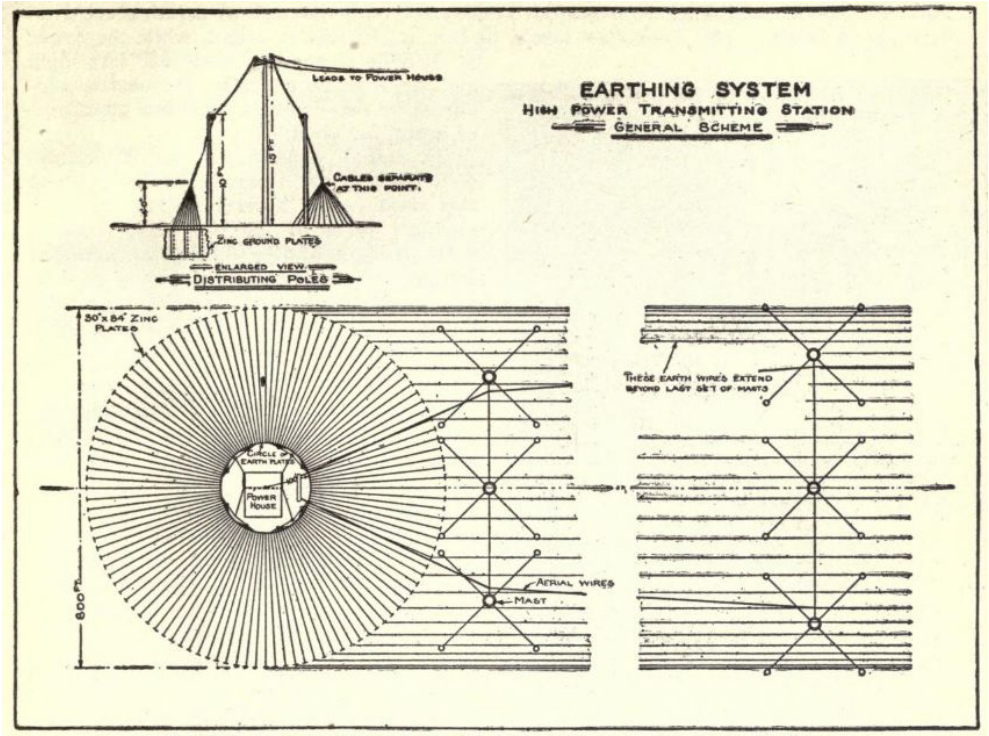
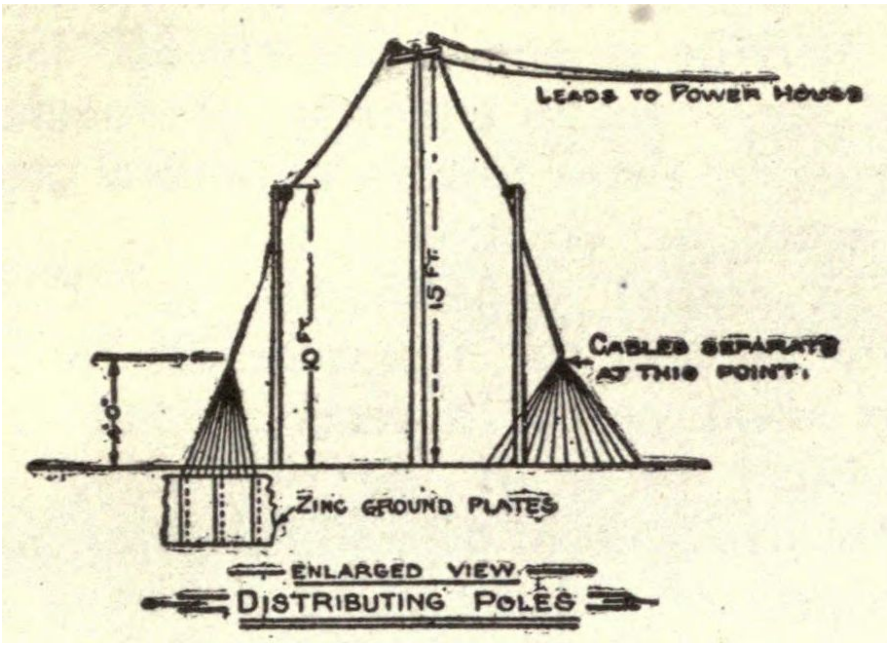


Fig. 320—General Scheme of Earth Connections for High Power Stations.

44. *General scheme of earth field surrounding power house for typical Marconi stations (Bucher op.cit, p.305, Fig. 320, originally published in* The Marconigraph, *September 1913, pp.548-549), and the type claimed by Fleming to be installed at Carnarvon. The upper left schematic (see detail at* **45***) appears to be realised in the image of the transmitter house (see* **26***), which includes the telegraph pole and cone of wires leading into the ground, where wires would then lead out around and beneath the antenna. The outer ring's presence or absence at Carnarvon is not currently confirmed.*

Bucher's account of earthing at these stations drew heavily on an account published three years earlier, in *The Marconigraph* of January 1914, which he may have written. In a later, December 1922 document (Bodleian Special Collections, MS.Marconi.198), no mention of a second, wider earth ring is made, and the earthing plates are said to have been of galvanised iron, rather than the copper given by Fleming, or the zinc (which could have in fact meant galvanized iron) given by Bucher.

During fieldwork for this report, galvanised iron sheet was found encircling the concrete bases of the elevated counterpoise lattice masts for the 1923 extension which may lend some weight to the earlier use of the same material for earthing at the transmitter buildings.



45. *Generalised early earthing system, as used at Carnarvon. Iron fence posts seem to have been used at Carnarvon, from which the fan of wires spread to the ground plates. This would provide the correct general height indicated in the diagram (4' 0"). From Bucher, op.cit,. p.305.*

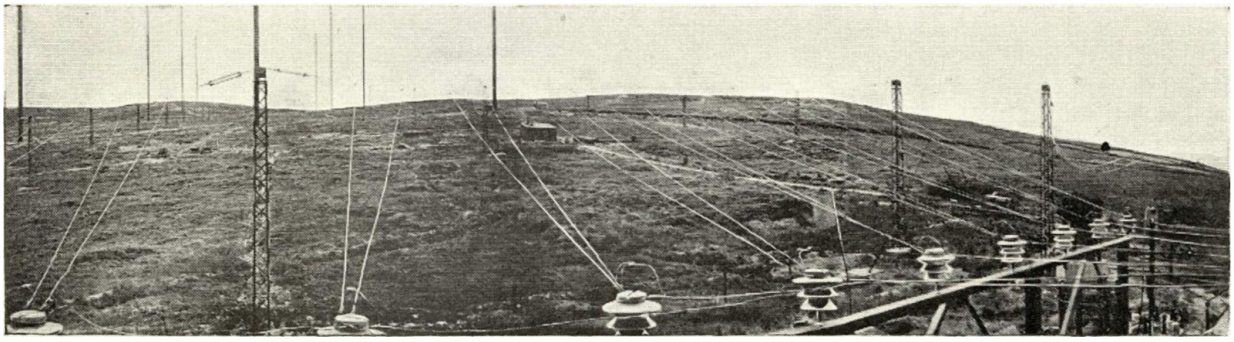
46. *Whilst mobile, boggy ground has obliterated the fine detail of the lower reaches of the Carnarvon antenna site, a photograph of the earth screen – on very dry ground – at Bolinas, CA, shortly after installation shows how an earthing ring (which was irrigated by a 3/4" water pipe at the station) of 100 foot radius surrounded the transmitter building, with linear, buried wires leading away in all directions revealed by ground scars. The screen was led towards and over the cliff, and a connection, via a rectangular, 980 square foot plate, to the sea was made (Bill Ruck to Rowlands at Bolinas, pers comm 11/01/2023, with contemporary schematics examined but not released for publication). Image courtesy California Historical Radio Society.*

In his remarkably brief, poorly-written and thus unclear account of Carnarvon, Vyvyan, states (op.cit., p.66) that an elevated screen (more correctly, a counterpoise) of insulated wires – by this he meant insulated from ground, not wires covered by a jacket – supported at a height of "15-20 feet" above ground was employed from around 1921. He is not specific on the date, his whole account jumping around incoherently in time. It is suspected, from an account in *The Wireless World* (September 1919) of changing the number of radiating wires and hinting that general upgrading work was then underway, that the elevated counterpoise may have been built as early as mid-1919 – quite possibly the first post-war modification following the station's handing back to Marconi's by the Admiralty. It was certainly in place no later than mid-1921, as a photo in the Marconi C°. pamphlet (Bodleian Special Collections MS. Marconi 198, publication date unstated) can be fairly reliably dated from its content to late 1921 or early 1922, the photo being taken well before publication.

The Marconi C°. pamphlet (ibid.) gave the screen "a mean height of 24 feet", suspended from 30' lattice masts. The imprecision in Vyvyan's height estimate of the lattice supports adds further to the suspicion that he had, at least by this point, rather less involvement at Carnarvon than might be assumed.

During fieldwork for the present report, numerous steel lattice tower bases and remnants of the masts, depicted in the Marconi C°. pamphlet, were found around the 1914 antenna site. These grew, alongside interconnecting line features – possibly, but by no means certainly, trenches for the earlier, buried screen and visible both on the ground and in satellite imagery – into a pattern that clearly revealed the modification that was the elevated counterpoise system. It was remarkably extensive. All the outer masts have associated with them, always at 9 yards for both the 1914 and 1923 arrays, iron eye-bolt stay anchors. Some examples of non-outer masts also have such anchors. Only one such stay was found in association with any given mast, so they appear to have been backstays only.

The pamphlet image shows no sign of the two, large extension pylons to the rear of the antenna, nor the later, 1923 extension, either under construction or completed. The overall details given in the pamphlet of transmitters in place and those "recently dismantled", and the lack of any extension towers, gives a late-1921 to early 1922 date of publication for the pamphlet, the photo being some months earlier, during 1921, given the scene is a mid-year sun elevation. The 500' extension must therefore have been installed after summer, 1921. Vyvyan is not explicit on the date of this important extension and there are no known photographs of the two enormous pylons.



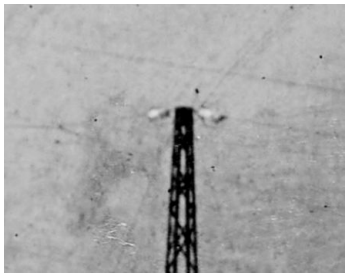
47. *A very wide-angle, poor quality image from the 1921 or 1922 Marconi C°. pamphlet (op.cit., p.4), showing the steel counterpoise mounting frame and distributing insulators to the immediate front of the transmitter building, and the span of the counterpoise wires and their supporting 30' lattice masts. The counterpoise was installed sometime between 1919 and 1921.*

Vyvyan's claim that the first, buried screen was "800' wider than the antenna" is not correct. This figure seems to have been taken from the Bucher/*Marconigraph* article, where the *diameter* of the screen – centred on the transmitter building – is given as 800'. The Carnarvon property boundaries, notably to the south, and detail from sites such as Bolinas, California, strongly suggest the original, buried wire screen was either no wider than the radiators overhead (*The Wireless World*, December 1913, contemporary with the building of the station, states at p.536 that the wires were "buried underground, immediately beneath the aerial"). Survey indicates they ran as far as just inside the outer mast stay anchor blocks.

The later, elevated counterpoise for the 1914 antenna is definitively shown not to have exceeded the limits of the overall structure, the outer screen masts revealed during survey and in a single photograph (see **47**) lying just inside the outer stay anchors in order to allow the counterpoise wires, at only around 24 feet above local ground, to pass beneath the steeply sloping stay wires. The property boundary to the south, and the retention of symmetry, dictated the limit of the screen. Fragments of wire that were probably part of this counterpoise were occasionally found, being 6-strand copper wire of 3mm total diameter.

Small parts of the 1923 extension's elevated counterpoise system are seen in several photographs of the antenna tuning inductor buildings and of the general site. Whilst most counterpoise lattice bases (and one length of wire at the foot of one of the supporting lattices) were positively identified from the 1923 extension, the undergrowth at the lower end of the site makes finding all of them all but impossible and, with the pattern clearly elucidated, largely unnecessary. The elevated counterpoise for the 1923 antenna extended 325', widthwise, beyond the outer radiating wires on each side (total counterpoise width of 650').

48. *A typical concrete base for an elevated counterpoise lattice mast of the lower, N°.1 antenna array after ca. 1921, with remains of the mast legs (1¾”x 1¾” L-section steel). Many of the bases can only now be found when the pattern of installation is worked out from those few that are more readily found, and the pattern of shallow trenches for ground wires that are still seen to run between them. The bases in many parts of the lower end of the lower antenna are now fully buried by deep bog growth, whilst the bases for the 1923 extension are typically overgrown by dense, tall heather and, at the lower end, by bog growth. Trowel blade = 6”/15cm, bases typically 35”x35”, lattice sides 20½” x 20½”.*



49. *A counterpoise base (concrete of 4’ x 4’) for the 1923 extension/upper array, showing remnant lattice ironwork (32” x 32”) and two large tubular insulator fixings, now known from detail visible in MS.Photogr.c.243 image 718 (inset, right) to be used to strain the wires at the tower; a ‘jumper’ wire interconnected both sides of the counterpoise wire over the tower. Concrete = 4’ x 4’.* 53.121962°, -4.169796°

50. D*etail of a 1923 counterpoise system insulator fixing (galvanised iron and ceramic).*
53.122355°, -4.171794°

The wet conditions at the station, which persist even in hot summers, would lead to a reasonable ground conductivity that assists the efficient operation of antennas. But the installation of a wire ground screen/counterpoise would significantly improve ground conductivity and thus efficiency. An account for the *Engineering* periodical in the Marconi archive (MS.Marconi.198) recounts how the installation of the elevated counterpoise reduced the power required for the same, 300A current in the antenna by 70kW.

As already noted, cuts in the ground, still readily visible today across (and not along) the whole 1914 site, are of uncertain specific purpose, but were certainly related either to the original, buried earth screen, or the later, elevated counterpoise. No wires have been found in light excavation at three points in different cuts, but this is not surprising as salvage from the site was remarkably complete. It is likely that they did contain wires, perhaps that interconnected the original earth screen wires running W-E, in the long axis of the antenna, creating a grid. But this is not what appears at other Marconi sites around 1914, suggesting it was an addition at the time of the elevated counterpoise's installation, connecting lattice tower grounds. An especially clear line, uniquely clear of vegetation, is visible within the (private) grounds of the lower section of the antenna, showing a narrow cut in the ground and discounting the unlikely possibility these features were trackways for the installation of the elevated counterpoise system.

51. *Arrows indicate obvious cuts in the ground running along a roughly N-S line between counterpoise masts (or existed beforehand). The cuts are also obvious from ground level.*

52. *Detail from a larger photograph, showing the two nuts used at the base bolts. A wire is compressed between these particular nuts, which appears to be the 6-stranded copper ~2/16" (~3.2mm) wire still seen occasionally across the 1914 site (see* ***53****, below). This appears to have been for tower earthing. Bodleian Special Collections, MS.Photogr.c.243, document P.2092)*

53. *Remnant wire found at the upper end of the 1923 extension. This is 7, rather than the 6-stranded wire generally seen around the 1914 site, though 7 strand was originally specified for the 1914 antenna.*

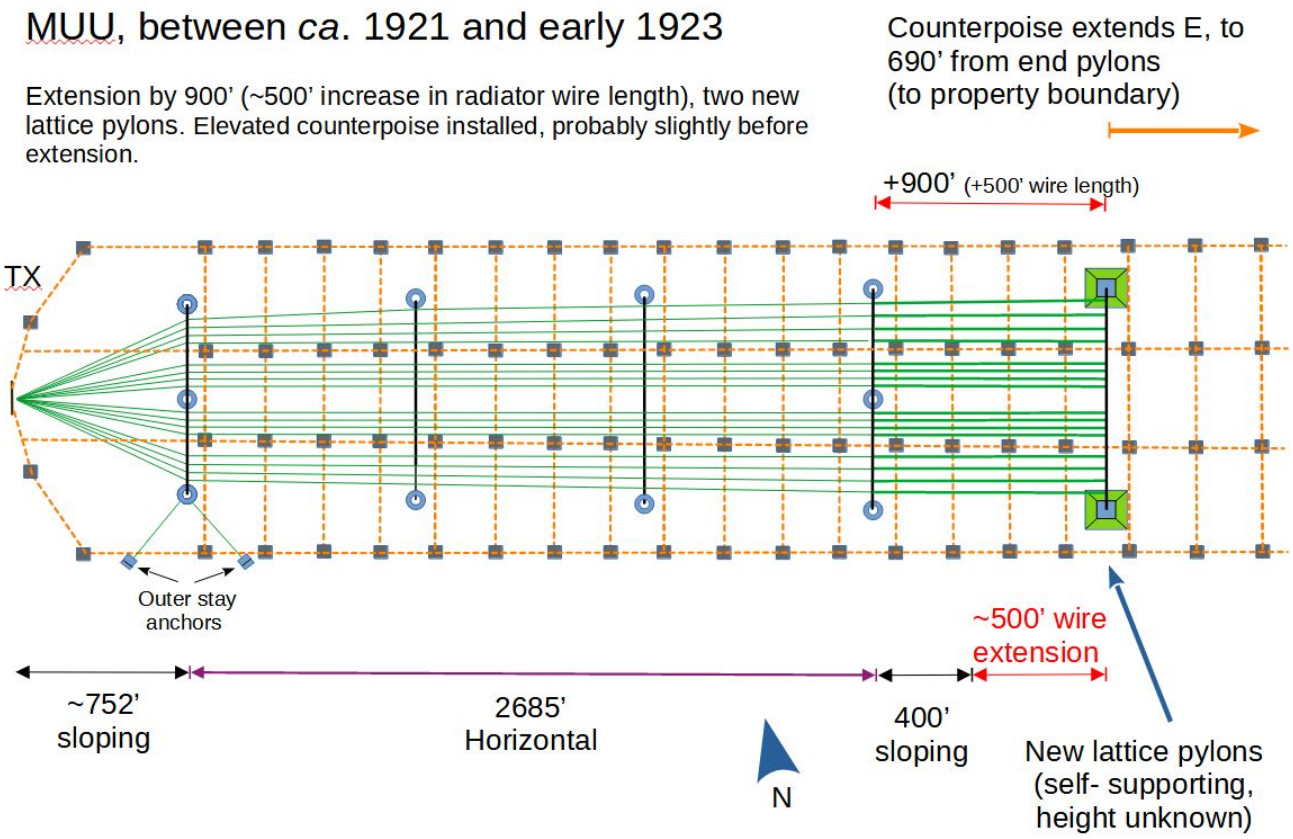
54. *A late discovery during fieldwork, this smaller concrete anchor block, which had an iron loop attachment to a sloping face and probably serving to backstay the counterpoise masts of the 1923 extension, shows a thin copper strap that bends over the rear of the concrete to earth. The wires running to the block were earthed via this strap. A piece of discarded, light steel wire (***55***, below) was discovered to the northern limit of the 1923 antenna's counterpoise, showing a neat winding of copper wire that likely made the connection to earthing straps like this. Identical windings were discovered in late 2023 on early AC transmission pole stay cable remains at Cwm Dyli. The Marconi site example was almost certainly a stay wire for one of the counterpoise masts.* 53.123782°, -4.165569°.

55. 53.124525°, -4.173295°

56. *Looking uphill (east). The elevated ground screen is in place, as are the two shorter steel towers, which an account written for* Engineering *journal (Bodleian Special Collections, MS.Marconi.198) indicates is the forward radiator wire straining system that was a later addition and not part of the original, 1914 antenna. The wires are recounted as meeting at a common anchor, still present, to the west of the buildings – seen here converging towards the ground, at far lower left foreground. The ~500' extension masts to the rear are not seen. Date unstated. From the content of the pamphlet in relation to "recent removal" of timed spark transmitters (October 1921), the existence of Alexanderson alternators (from early 1921) and valves (1921), the absence of rear pylons (ca. 1921, uncertain) or the 1923 extension masts, the date of the photo is likely to be around mid-1921, the pamphlet itself somewhat later, perhaps very late 1921 or early 1922. The rear extension of ~500' must therefore have happened around mid-late 1921, as they were already removed by early-mid 1923.*

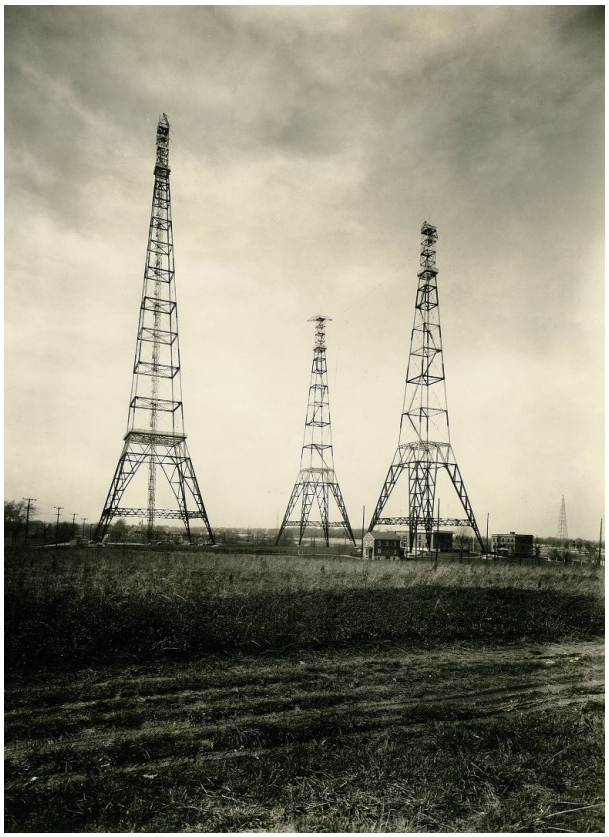
The 1921 Extension of MUU.

Around 1921 – the exact date is unclear – the original, 1914 antenna was extended linearly by about 500 feet, uphill, to 900’ from the previously easternmost three masts (cf. **34**). This required the erection of two, very substantial, square-based lattice pylons of 60’ sides. No reference to their height, but presumed to be 400', has been found as yet. Surprisingly, there are no known images or descriptions of the extension pylons or wire arrangements. However, the concrete bases for the pylons, their centre points being at precisely 900’ from the uppermost 1914 masts and thus confirming their purpose, are substantial and prominently visible today; their form was likely tapering.



57. *The ca. 1921 extension of ~500ft, to end 900ft from the original easternmost masts. The earlier buried ground screen was replaced with an elevated counterpoise system, probably slightly ahead and in anticipation of the extension. Not to scale. Two example outer stay anchors shown to indicate widthwise extent of counterpoise. The radiating wires (green) are indicative only and, for clarity, do not represent the installed number. Elevated counterpoise in orange dash. ‘TX’ = transmitter.*

Due to their poor geometry with the planned 1923 extension, the two 1921 extension pylons were removed at, or somewhat before that time. They were certainly gone by mid-June 1923, as proven by a chance discovery of a wrongly-filed, single photograph of Carnarvon from June 1923 within the archive folder for Brentwood and Ongar stations (Bodleian Special Archives, MS.Photogr.c.244, document 737/x – see **65**). The masts were in place for only two years or so – a very expensive temporary installation, but one that hints at the lucrative nature of sending messages across the Atlantic.



58. *These tapering lattice pylons at Arlington, VA, USA show the general likely form of the ~1921 extension pylons at Carnarvon. Image dated June 1923 (i.e. approximately two years after MUU extension at Carnarvon). U.S. Naval Observatory Library via Smithsonian Institution.*

There is some evidence to suggest the ca. 1921 extension, and perhaps even the 1923 array were, at least in part, a response to events of the latter part of the Irish War of Independence which had, by December 1922, led to the establishment of the Irish Free State. A report in the leading Home Rule newspaper, *The Freeman's Journal* of Friday, August 11th, 1922 ('Irish Takeover', p.4.), tells of the seizure by the Irish of Waterville and Valentia transatlantic cable stations, both in Co. Kerry. This immediately led to Marconi's wireless Traffic Manager describing the situation as "chaotic". Marconi's were "doing their best to clear off an increase of more than 100 per cent in messages". The Carnarvon staff was "being increased to rush the messages through". An official at the Post Office Cable Service stated that staff were working "fourteen hour stretches instead of eight", the effect of the chaos being "chiefly in the financial and Stock Exchange messages between New York and London". The critical role of wireless in modern society was now clear for all to see.

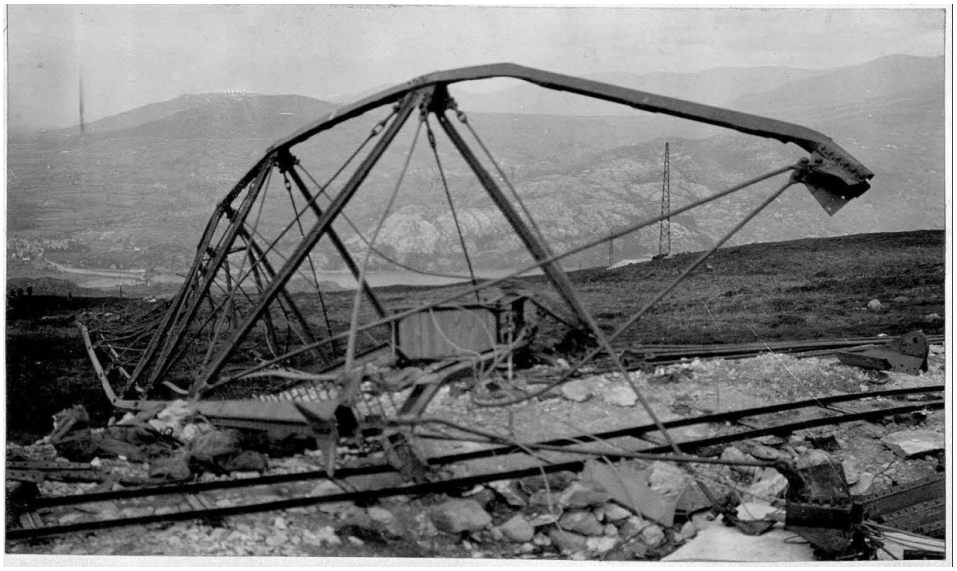
The 1923 Extension to MUU.

In January 1924, *The Wireless World* (pp.553-554) featured an article entitled *Carnarvon's New Aerial*, consisting, it reported, of six new lattice masts, each 400' high. Vyvyan (op.cit., p.66-67) recounts the same, new antenna and the six masts holding it aloft. This was to extend the 1914 antenna, the two wire arrays then acting as one antenna, still under the callsign 'MUU'. The extension was described in *The Wireless World* article (op.cit. p.554) as being "inductively coupled to the former aerial system on the principle of the multiple-tuned aerial", though the term "multiple tuning" did not indicate – and there is no archive or physical evidence for – tuned vertical radiators along the length of the antenna, as is the more usual meaning of this term. The slopers at both ends of both arrays were, however, dominantly vertically polarised and tied to earth via inductors, becoming a half-loop form of antenna (see **64a**).

The Wireless World account (op.cit., pp.553-554) contains photographs of the extension well under construction, confirming, as does the Marconi archive, that the work was begun during 1923. Vyvyan (op.cit., p.66) asserts it was completed and into service in December 1923. This does not appear to be correct; the array was still under construction in photos dated January 1924, as was the double ATI house, then without a porch, wire strainers or, presumably, the apparatus within. A spring-summer, 1924 first operation date seems in keeping with the evidence, provided the archive dates are correct, of course.

The Marconi archives photos reveal that Mast 13 completely collapsed, falling to the north-east, almost parallel to the still-extant dry stone wall running downhill, being partially buried in the very soft, boggy ground in the process. The reason for the collapse is not certain at the time of writing, but would seem likely, from the extent of the damage, to have been a failure in the stay cabling, possibly in anchor 13A (later 17A). The article *'Insulated Joints in the Wire Guys for Masts'*, *The Wireless World*, April 1914, pp.31-32, details how stay cable securing rings and other attachments sometimes failed in other installations due to poor technique and/or flaws in materials. The archive contains collapse photos from other sites, notably of very similar masts to the Carnarvon 1923 extension, at the Ballybunnion Marconi station, Ireland – callsign 'YXQ' (MS.Photogr.d.47).

A substantial component, almost certainly from this collapse, was discovered by chance during the fieldwork for this report (see **60, 61**). The replacement mast, for reasons of preserving a narrative and, no doubt, of superstition, was reassigned as Mast 17.



59. *Total collapse of Mast 13 in a photo dated June 1923. The replacement was built on the same foundation blocks, but reassigned as Mast 17. Bodleian Special Collections MS.Photogr.c.243, photo 730/x.*

60. *A chance discovery of a small, projecting piece of iron, made near to the field wall running down the hillside, revealed a large remnant that, on further examination, was seen to almost certainly be an upper part of the ill-fated Mast 13. Approximately 2' by 1½'. It appears to still be connected to a bracing rod, now buried in bog, under the apex at lower centre left. North to centre right.* 53.125259°, -4.171007°.

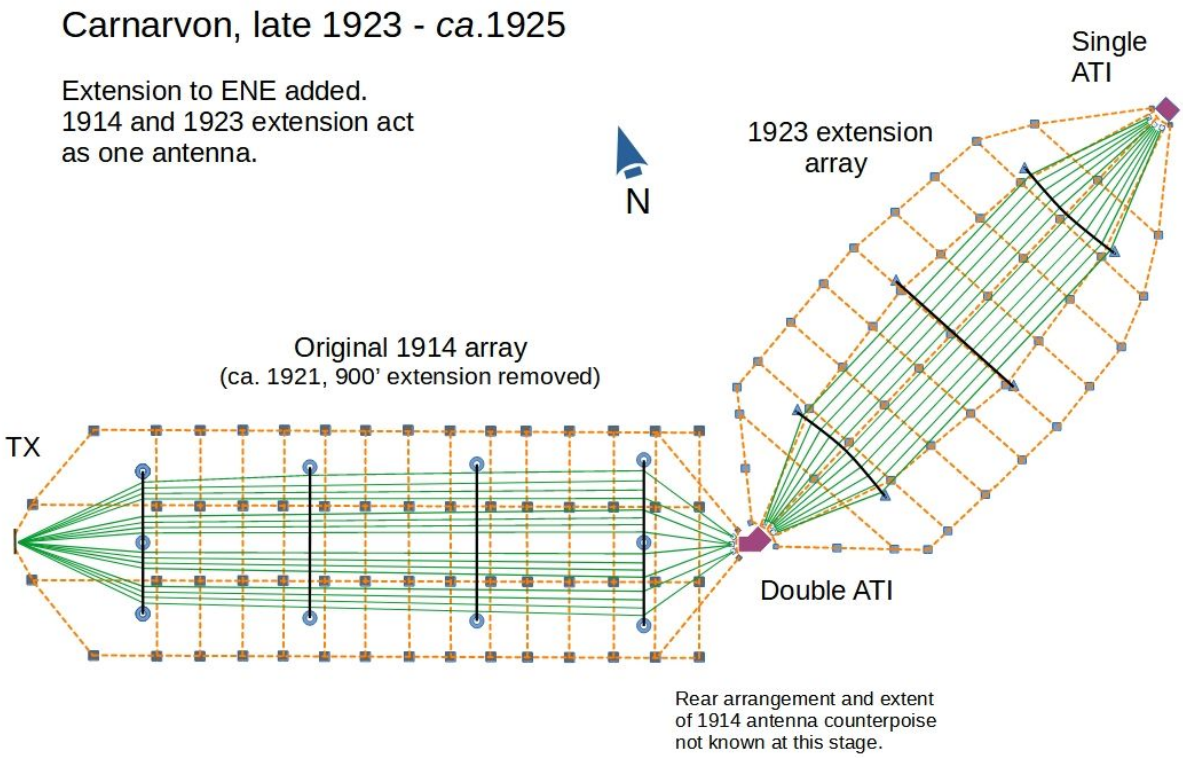
61. *View of the end to which the fixing attached to Mast 13.*

An area of concrete, seen in photos to probably have been a built-up area to assist track access near the base of Mast 13/17 was deliberately broken up, seemingly immediately after the mast's construction. A number of blocks of this broken concrete were later incorporated into the walls of a small fold or hut built against the adjoining field wall. Many of the concrete pieces are by now covered in bright green moss pillows, highly reminiscent of such growth on ancient Icelandic lava flows.

62. *Mixed stone and broken concrete from Mast 13/17 construction, fashioned into a rudimentary fold or hut built against a field boundary wall (to rear).* 53.124712°, -4.171576°.

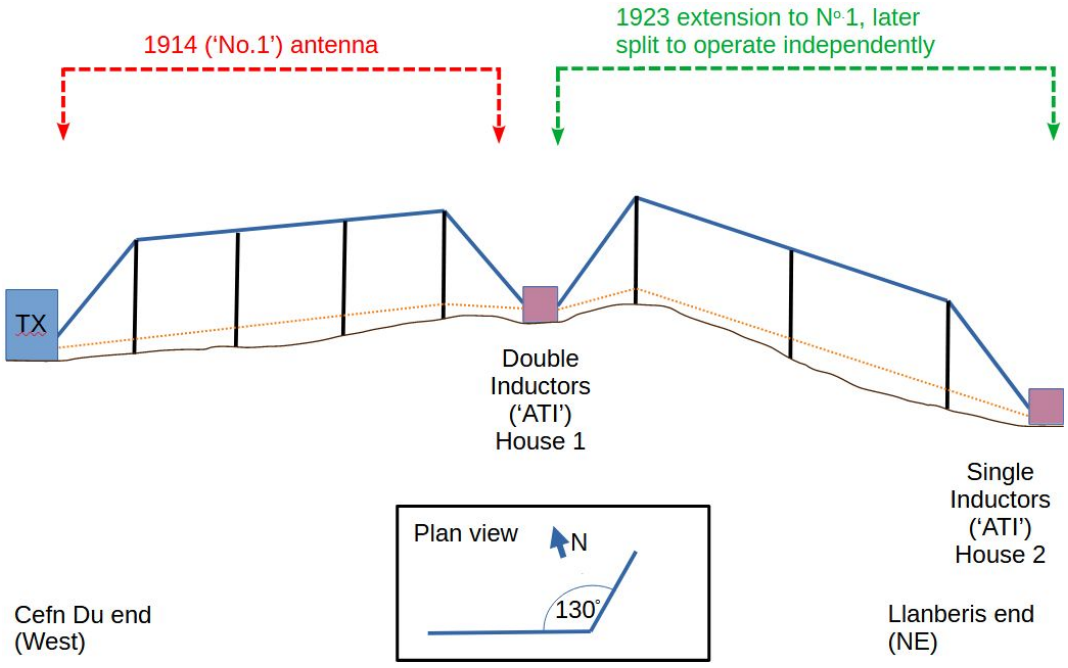
To the NW of the where the collapsed mast came to rest, an iron ladder sticks up incongruously from a boggy flat area of the hill. Further down the hill, other sections of ladder are found amongst the heather. The length and position of the sections suggest they were part of the ladder that ran up tower 13. It is a significant amount of metal that was, for some reason, never salvaged from a site otherwise extremely thoroughly cleared.

63. *Part of a ladder that probably ran inside Mast 13 before it collapsed. A mast-connecting section running at 90 degrees to the plane of the rungs can be seen running, partly-buried to the left at ground level (and unseen, extending to the right also). It is thus thought to have been the topmost ladder section, emerging onto a platform, as all the other connections to the mast were in the same plane as the rungs.*
53.125843°, -4.171668°



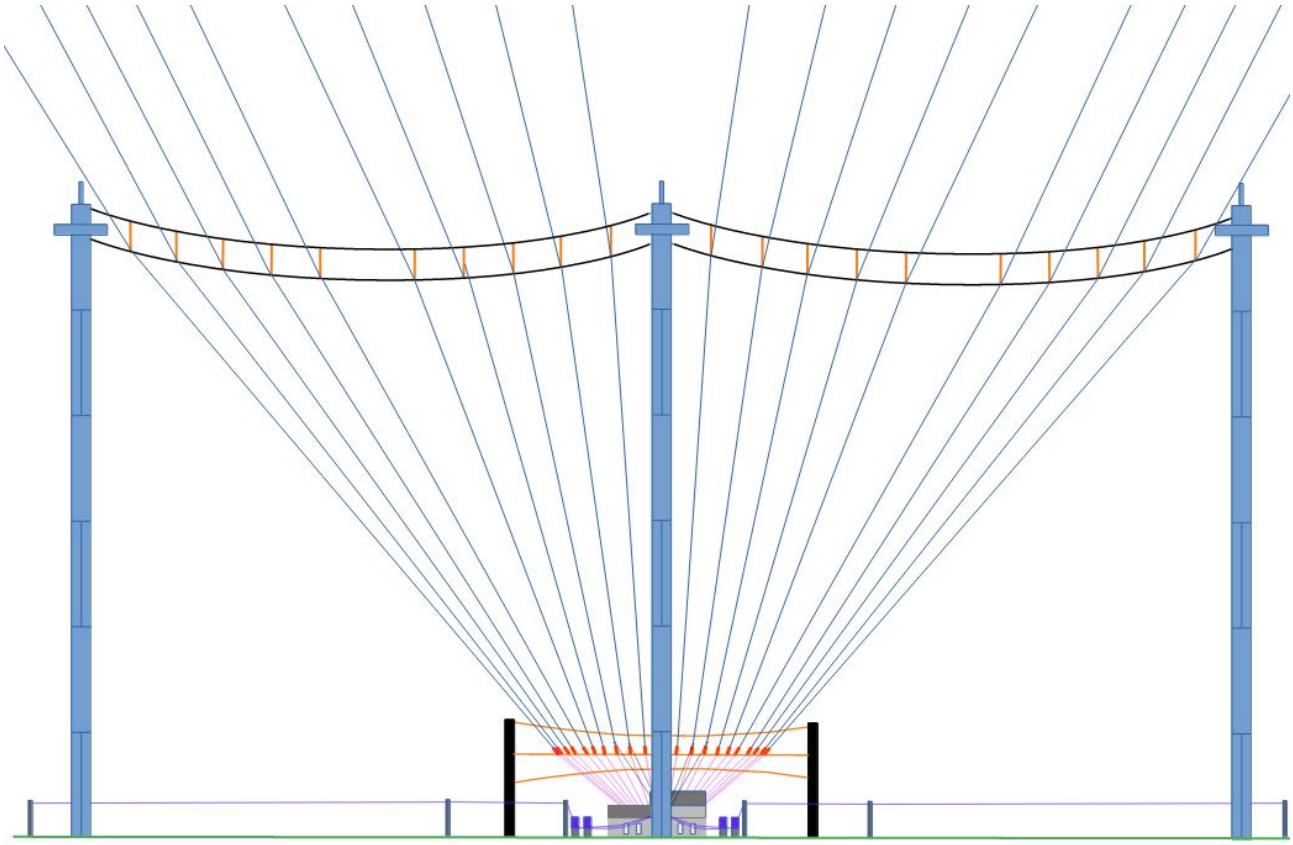
64. *The two arrays, acting as a single antenna. Official surveys as late as 2016, rather disappointingly, recorded that the offset shape, as viewed from above, was the meaning of the term 'inverted-L' (GAT, Report 1302, March 2016). Not to scale, number of radiating wires (green) indicative only. Counterpoise in orange dash. 'TX' = transmitter; 'ATI' = Antenna tuning inductor [house].*

64a, *below. Schematic side profile of the extended MUU antenna as viewed from the south. Elevated counterpoise in dashed orange line. With the radiators now grounded, the antenna took on a 'half-loop' electrical form. Not to scale.*

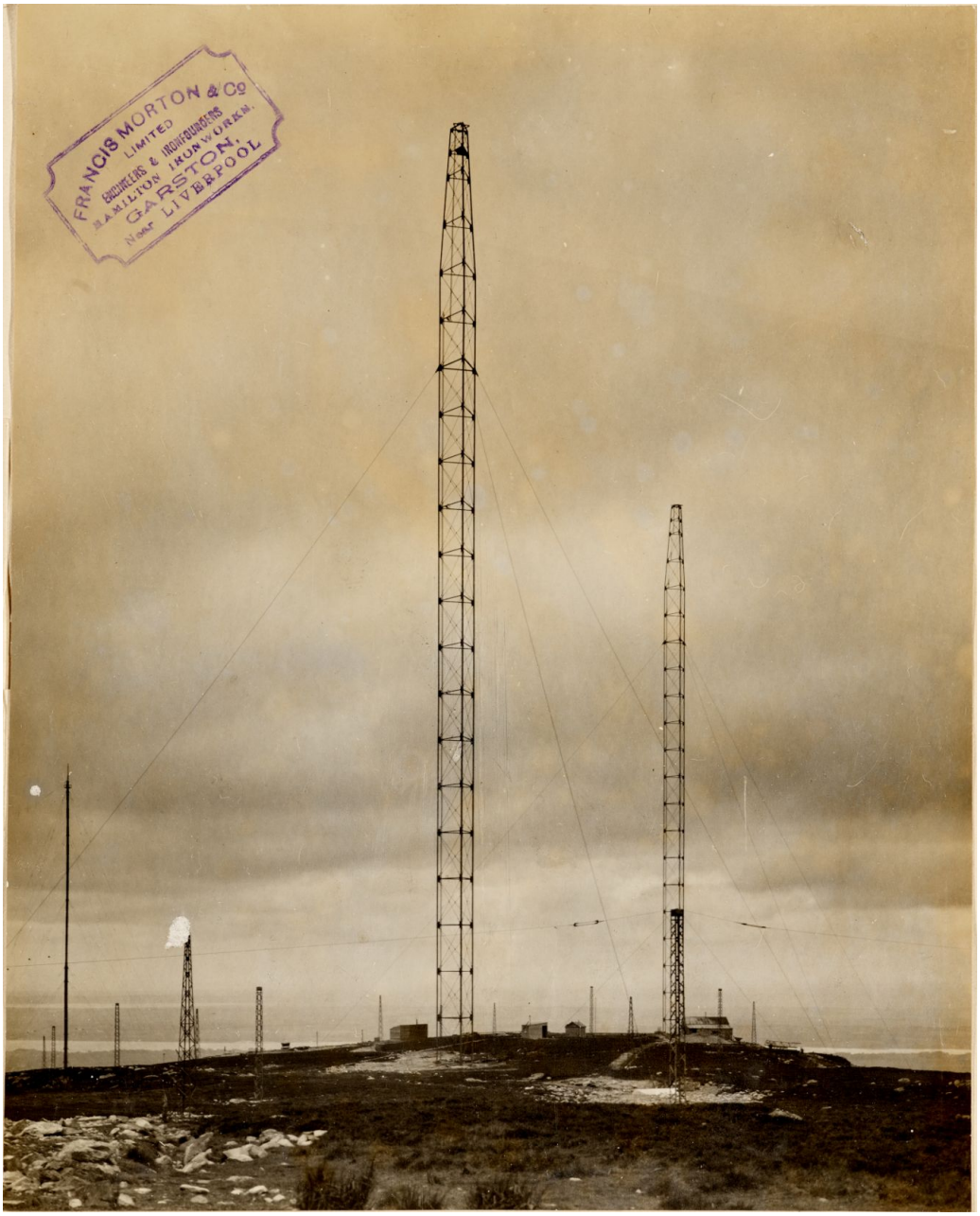


The length of the 1923 extension's antenna wires (i.e. sloping vertical and horizontal components) was 2915'). As previously noted, the new extension did not use the *ca*. 1921, ~500ft linear extension to the 1914 antenna, and its pylons are definitively seen in two photographs (see **65**, **136**) to have been removed no later than mid-1923. The 1923 extension array was served by tuning inductors at both ends – one inductor set within the eastern end of the double ATI house, the other within a similar, smaller single ATI at the NE/Llanberis end. Thus came about the "multiple tuning" mentioned earlier, as most of the radiation occurred from the sloping end wires of the arrays.

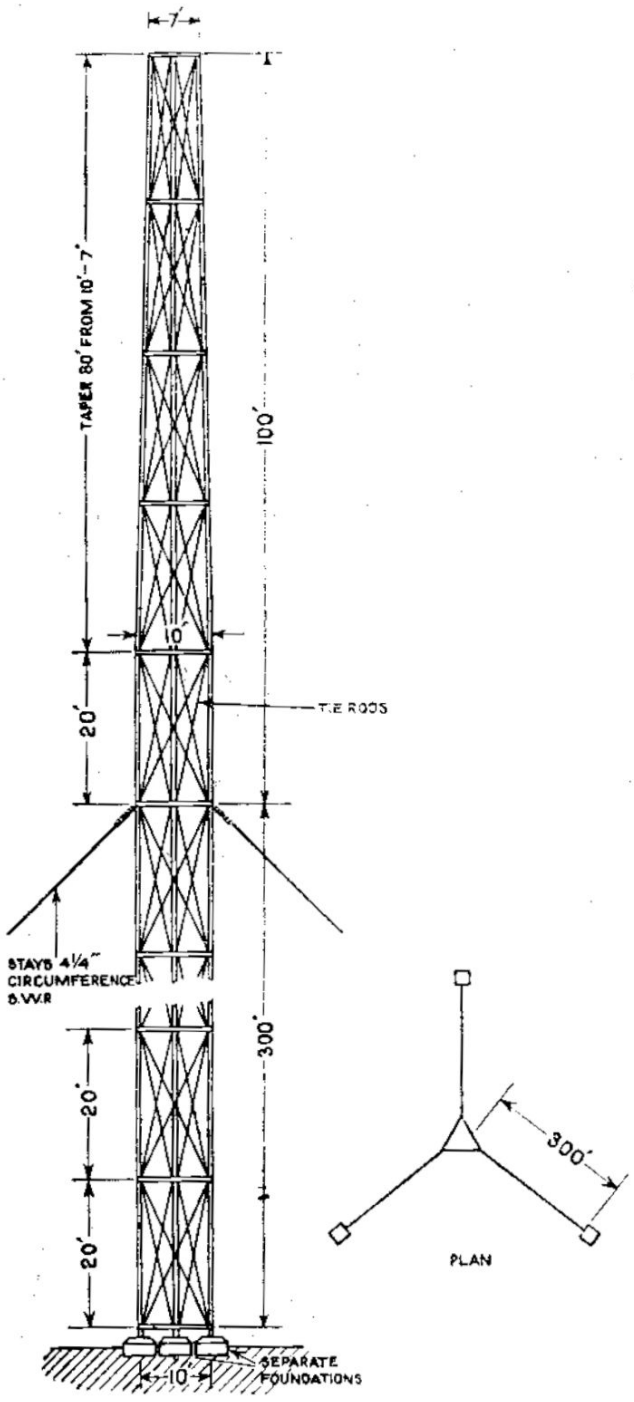
The orientation of the 1923 extension made use of land that was available for its construction, and was not due to the supposed directional properties of the antenna type; the principal traffic was still to the USA. By 1923, it had already become clear to the Marconi engineers and others that this was not a directional antenna, although Marconi himself would probably have been reluctant to admit this in public, having made so much of it in earlier years. The reason for the extension was said to be to allow "a higher transmission speed throughout the 24 hours" (*The Wireless World*, 30/1/1924, p.553). The issue at hand was likely bandwidth limitations due to the high 'Q' factor of the antenna, resulting in the antenna taking time to dissipate its stored energy and thus limiting the time within which a 'mark' (key-down) Morse (CW) signal could be distinguished from a key-up 'space' (*High-Speed Frequency-Shift Keying of LF and VLF Radio Circuits*, H.Wolff, IRE Transactions on Communications Systems, Vol. 5: 3, December 1957). The extension was only intact for about a year, so was either not successful or two antennas were found to be more efficient. New transmission modes could also offer effective resolution to high-Q antenna problems.



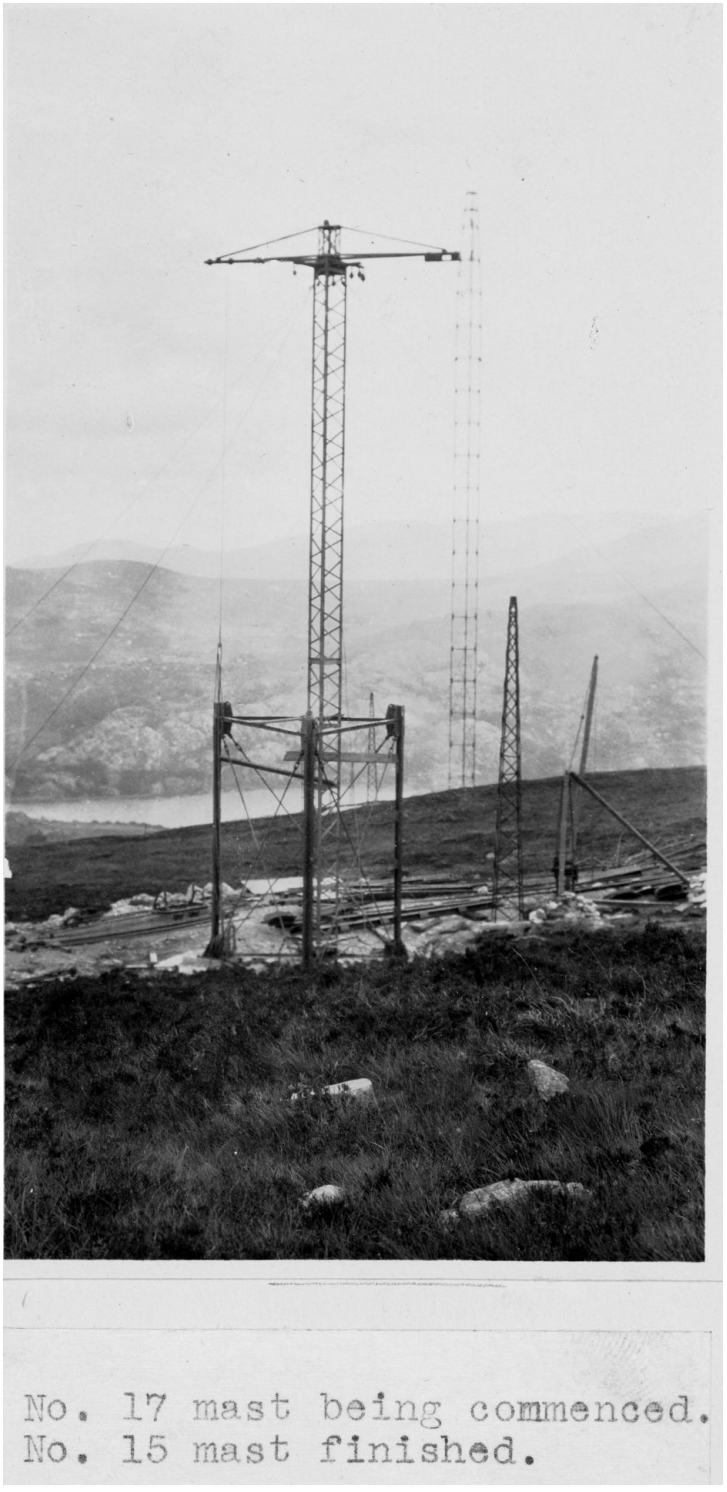
64b. *Front wire feed and straining arrangements at the front (western) end of post-1921, No.1 array as seen looking WNW, towards the transmitter house from behind the first mast row. This was a considerably more engineered system than the 1914-ca 1921 arrangements, but with 20 rather than 32 radiators. The triatic insulators seem to have been simple ceramic rod types.*



65. *An extremely informative, chance-find photograph of Carnarvon's extension to the NE from June 1923 (MS. Photogr. c. 244, a file dealing with Ongar and Brentwood stations, Essex), which appears to be correct dating and labelled photo 737/x. Mast 11 lies, without triatic and antenna wire as yet, in the background, behind blockhouse 5 which has a mixed stone/brick extension to the original, entirely-brick building, for use during the antenna extension's construction (see Appendix IV); blockhouse 6, out of shot to the rear of this photograph, is seen in photo 705/x of the same folder to already be missing its roof and semi-derelict by 1923, only 9 years after the armistice. Mast 12 lies at centre. Various small lattices, mostly or all for elevated counterpoise ('earth screen') support feature prominently, as does the upper, northernmost tube mast of the 1914 antenna, lower far left. What may be wire strainer poles are just visible above the horizon of the summit, lower left, though they were redundant by this time. The ca. 1921 extension, northern Pylon A, would dominate the view between the 1914 mast and Mast 12, but has clearly been removed by this point; one of its concrete base feet is visible when the image is viewed at original scale.*



66. *Schematic of a supporting mast for the 1923 extension to the 1914 antenna.* The Wireless World, *January 30th, 1924, p.554. The distance between base centres (and hence the width of each side of the mast) is is not that seen on-site; the measured distance of the installed base centres is 176", or 14'8". The base-stay anchor distance denoted in the inset of the mast, stays and anchors, is correct. Other dimensions cannot be checked. The top of the schematic mast is also clearly different from that installed.*



67. *Mast number 17 (foreground) was originally (unlucky) number 13, which collapsed. Here, the replacement mast is being built using a rising central column system. Note the small mast alongside (right); this was part of the elevated counterpoise support. Bodleian Special Collections MS.Photogr.c.243 photo 713/x.*

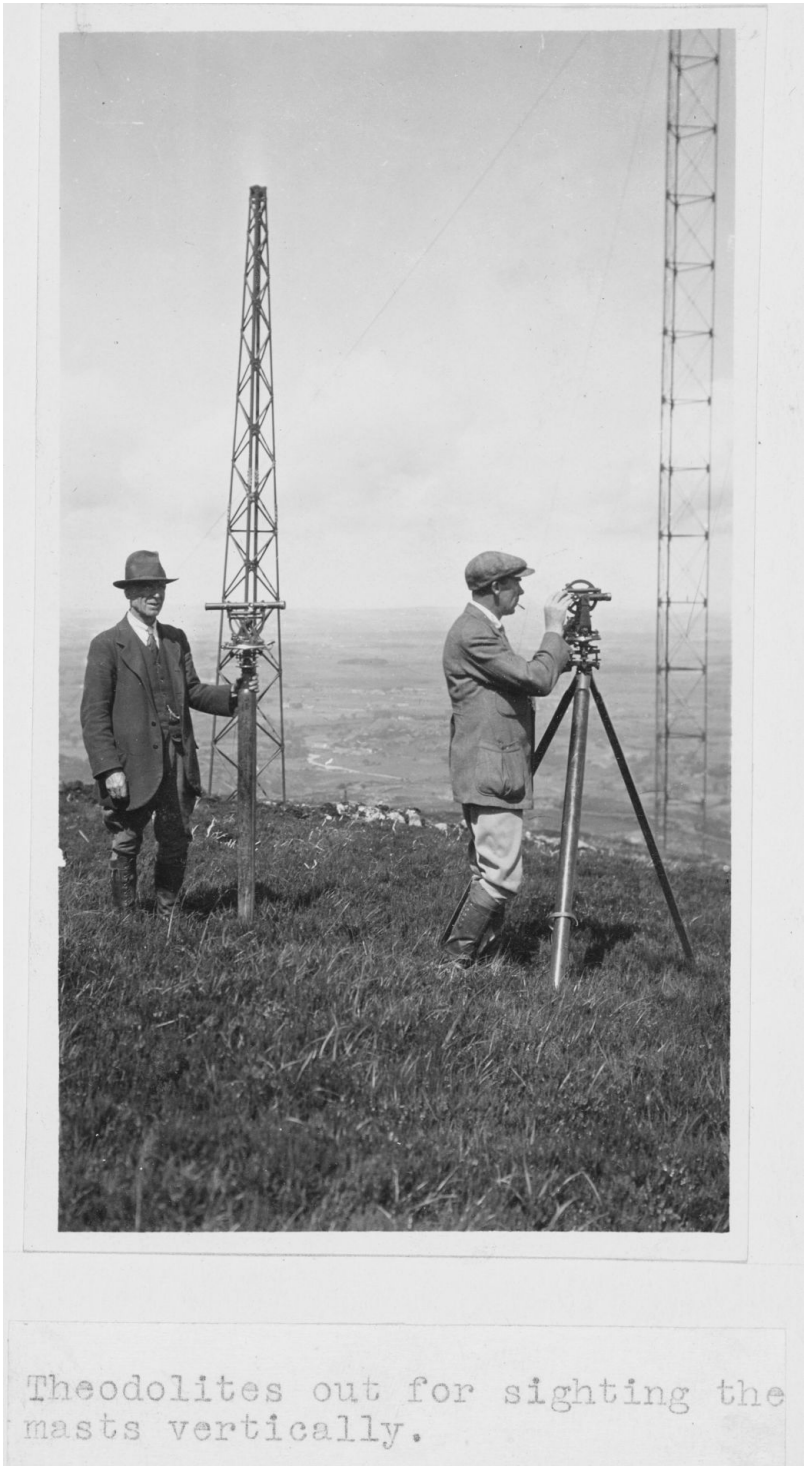
68. *Bodleian MS.Photogr.c.243 photo 733/x, showing failure of a shackle caused damage and may have been the event (the estimated height to the top of the main mast is about 90 feet) that caused the death of a worker, John Pierce Jones, in the same month (June, 1923), reported in the press (***69***, below, courtesy* The British Newspaper Archive). The Pall Mall Gazette *(also 5th June, 1923), on the same event, noted that Jones had just reached the top of the tower being built when he fell, being "killed instantly"; he left behind a widow and four children.*

69.

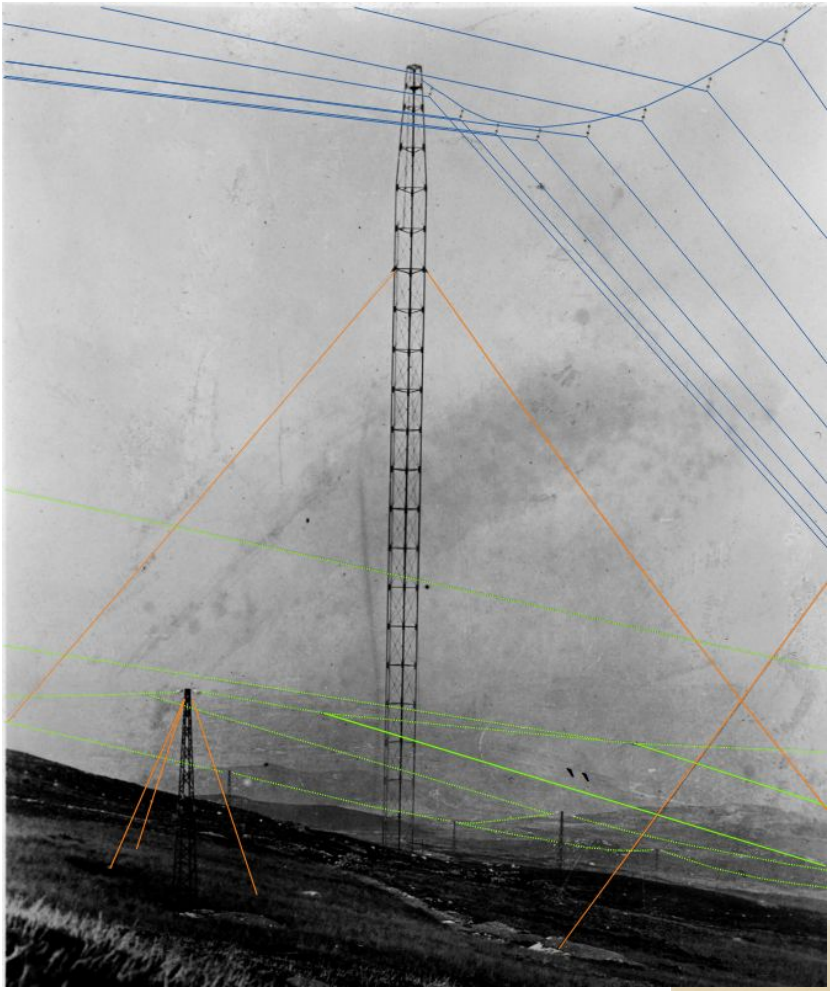
John Pierce Jones, Port Dinorwic, while erecting an iron tower in connection with the Marconi station near ..

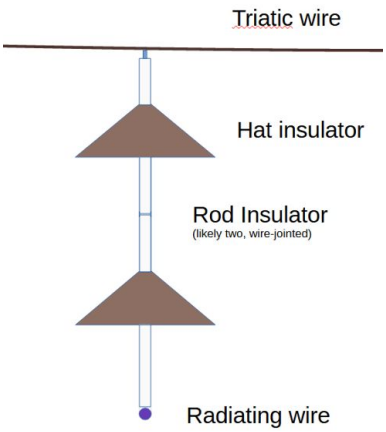
... John Pierce Jones, Port Dinorwic, while erecting an iron tower in connection with the **Marconi** station near **Carnarvon**, fell 82 feet, and was killed. The finished part of the Liverpool Cathedral to consecrated on July 19, 1924, the 20th anniversary of the ...

Published: Tuesday 05 June 1923
Newspaper: Dundee Evening Telegraph
County: Angus, Scotland
Type: Article | **Words:** 48 | **Page:** 2 | **Tags:** none



70. *Detail of a counterpoise lattice tower (left), as yet unwired. Many such towers are seen dotted around the antenna site in other photos which, with fieldwork in very difficult terrain, permitted the arrangement of the counterpoise system to be understood in full. Bodleian Special Collections MS.Photogr.c.243, photo 716/x*





70c

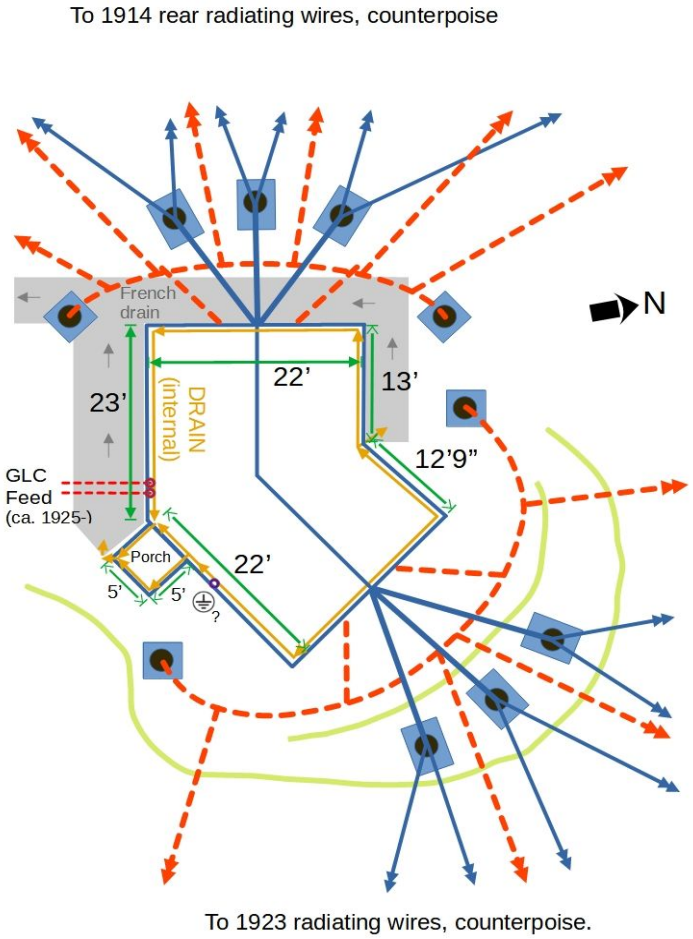
70a *(above) Photographed shortly after completion in 1924, the extension array radiating wires, hung from a triatic seen running between Mast 15 and the out-of-shot Mast 16, can be confidently traced out by careful contrast enhancement. Some of the elevated counterpoise wires (dotted green lines) are also evident, as are what may be tensioning wires (solid green) running from lower centre to lower right. The steeply-sloping wires to the rear, Llanberis end of the array, which terminated at the lower ATI house, are clearly revealed. The original image, MS.photogr.c.243, photo 718/x, is seen at* **70b**, *right.* ***70c****, radiating wire suspension schematic, at upper left.*

Double ‘ATI’ (Antenna Tuning Inductor) House.

The design of the extended antenna required inductors in addition to those used at the transmitter house, so that it could be matched to the transmitter (‘tuned’) and radiate efficiently. The inductors were housed in substantial buildings, one (the ‘double ATI’) erected between the rear of the 1914 antenna (now without its 1921, ~500ft extension) and the upper end of the 1923 extension, and the other (‘single ATI’) at the lower, Llanberis end of the extension. The double ATI had inductors for the upper end of the 1914 array and the upper end of the 1923 extension.

The ATI buildings were of steel or timber frame bolted to a concrete base and covered with corrugated sheet steel outer skin and possibly, from a dimpled fragment found in a drainage ditch, an asbestos sheet roof. The steel siding was confirmed by discovery of small fragments of the sheets still in place at the lower, single ATI site (see **74**) and much more limited evidence at the upper ATI.

The double ATI house was of a striking, angled form that allowed it to face both sides of the now single antenna composed of two arrays of wires.



71. *Schematic, not to scale, of the double ATI house and connections. Blue lines are connections to the radiating wires, dashed orange lines the counterpoise wires. Light green lines denote raised ground. From field and archive work for the present study, 2022-23.*

72. *A very atmospheric photograph of the double inductor ('ATI') house during construction in early 1923, taken from the east. MS.Photogr.c.243, photo 711/x. The dark line across the building appears to be an old water stain on the image. Note the slack wire running steeply from ground at lower right; this may be evidence the 1921 pylons are still in place. A rod-insulated wire is also seen and may have been for tensioning, acting forwards, but removed from its pole.*

Despite the large volume of broken insulators littering the concrete base, a December 2007 survey interpreted this feature (NPRN 505905) as "the footings for a radio station mast or pylon"– a spectacular failure to recognise it for what it was (Oxford Archaeology North accepted this was "probably" an interpretation error (OA North to Rowlands, pers. Comm., 26/8/2022), although the error is proven). The strainer masts in front of the ATI house and the line of remaining 29 (of 32 originally) wire strainers were included in the NPRN and also poorly interpreted as "anchoring points" for this or some other, unspecified antenna that was not ever there.

The concrete bases surviving around the perimeter of both ATI houses (which misled the OA North surveyor) are thus seen to have been for short lattice straining masts supporting insulated feeds for the counterpoise and radiating wires. Fragments of 3/16" (~4.7mm) patterned (obscuring) window glass – tentatively identified as Chance Brothers (Glasgow) 1911-1925 'Scintilla' Cathedral design – were also found on the ground adjacent to their installed positions. A system of channels in the concrete ATI base were arranged to drain water from within the building, being located well behind bolts for the securing of the building's frame. Although labelled many decades ago as being taken in January 1923, the sun azimuth and elevation that is derived from shadows, particularly that of the worker closest to the building, under the sunlit elevation, suggests it was taken later, around early-mid April. This may be supported by the fact that the workers are all in light clothing – turned-up shirt sleeves and waistcoats, which would be unusual in January at 1350' above sea level. The year is correct, because all accounts are of the antenna then being extended.

73. *Double ATI from the north-east (MS.Photogr.c.24, 745/x). The three lattice supports in the foreground were set on concrete bases on an elevated, rocky platform between the foreground and end of the building. The central base was sought and confirmed during fieldwork (see* **75***). Bodleian Special Collections.*

73a. *Detail from* **73** *of hatted strainer mast at right rear, showing a bilingual 'Danger' and (Welsh) 'Perygl' warning of what appears to be 10,000 volts (MS. Marconi 790, item 5, details valve tests, almost all with the anodes ('plates') at 10,000 V, in April 1926).*

74. *Small but definite remains of corrugated steel of the outer skin for the single ATI house, located at the NE end of the 1923 antenna extension, towards Llyn Padarn. Later work showed the upper, double ATI house was also of this same outer skin.*
Scale squares = 1cm, north to upper right corner.

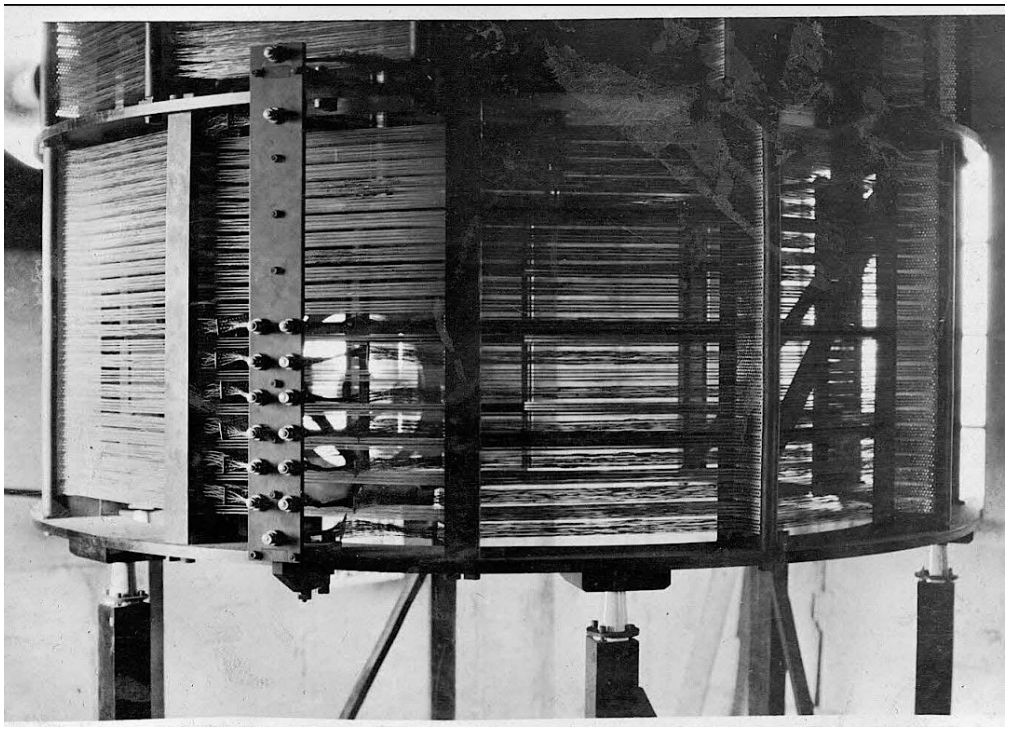
53.126232°, -4.165181°

75. *Light surface excavation revealed the base, with steelwork impressions, for the central straining lattice mast for the 1923 extension at double ATI (see* **76***). Yellow tape element open to 1ft.*

53.121432°, -4.175915°

76. *Straining towers of the upper (double) ATI, serving the 1923 extension.Bodleian Special Collections, MS.Photogr.c.243, photo 748/x. Lattice base measurements (nearest facing length in photo of 1156mm or 3’ 9 ½”) permitted scaling and a determination of an exact, 12’ height for the steel lattice. Wires to the hat are the antenna feed, the catenary of wires below being the counterpoise connections. The towers are seen to be grounded via copper straps at their furthest left-hand corner in each case. The mounted insulator and rain hat added about 3’ 6” to the height. The ceramic fragments at* **C40** *are consistent with the insulators mounted on the frame. Dated January 1924.*

77. *Light surface excavation revealed the porch base. Note drainage channels in concrete, which appear to have run on the inside of the building's skin. The drain for the whole building emptied at the lower far left corner of the porch. Porch is 5' wide (outer edges) by 69½" (to outer edge of drain channel). Tape open to 2'.*

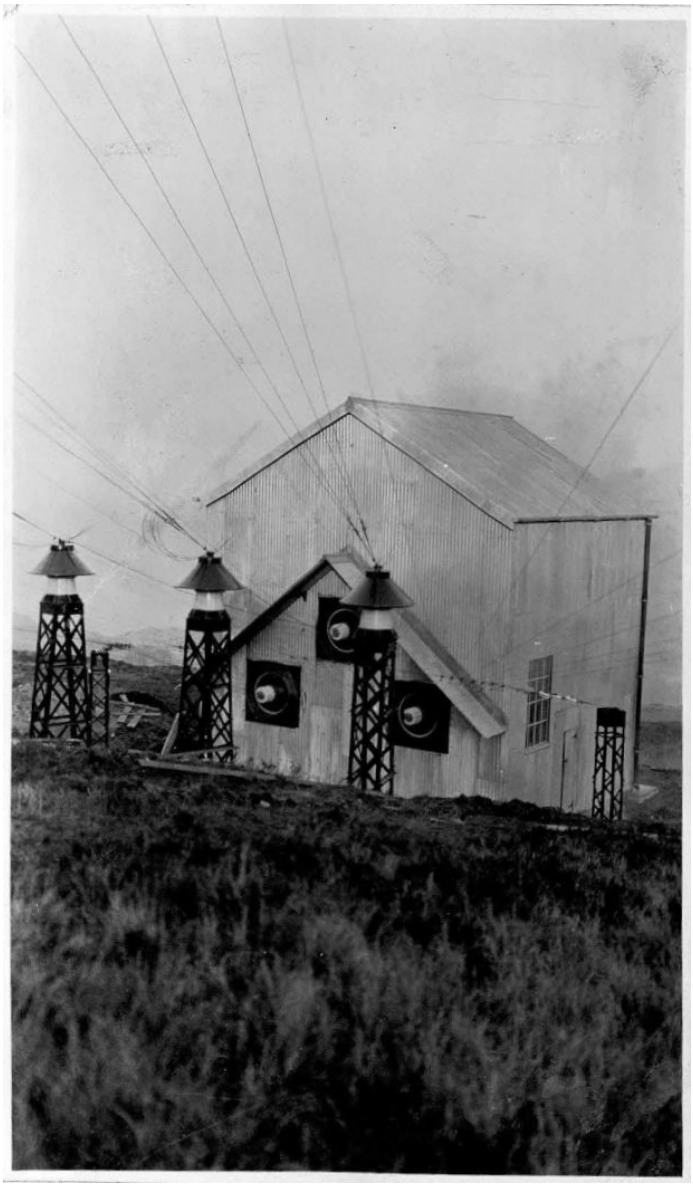


78. *One of the matching ('tuning') inductors for the 1923 extension side within the double ATI house. Counterpoise through-wall insulated connections (lower) and antenna feed (upper) are seen in the gable end at rear left, though it is not clear from the photo which of the two gables this was. Remains of this inductor and others litter the double ATI site. See Appendix I for more detail about this inductor. MS.Photogr.c.243, image 747/x, January 1924.*

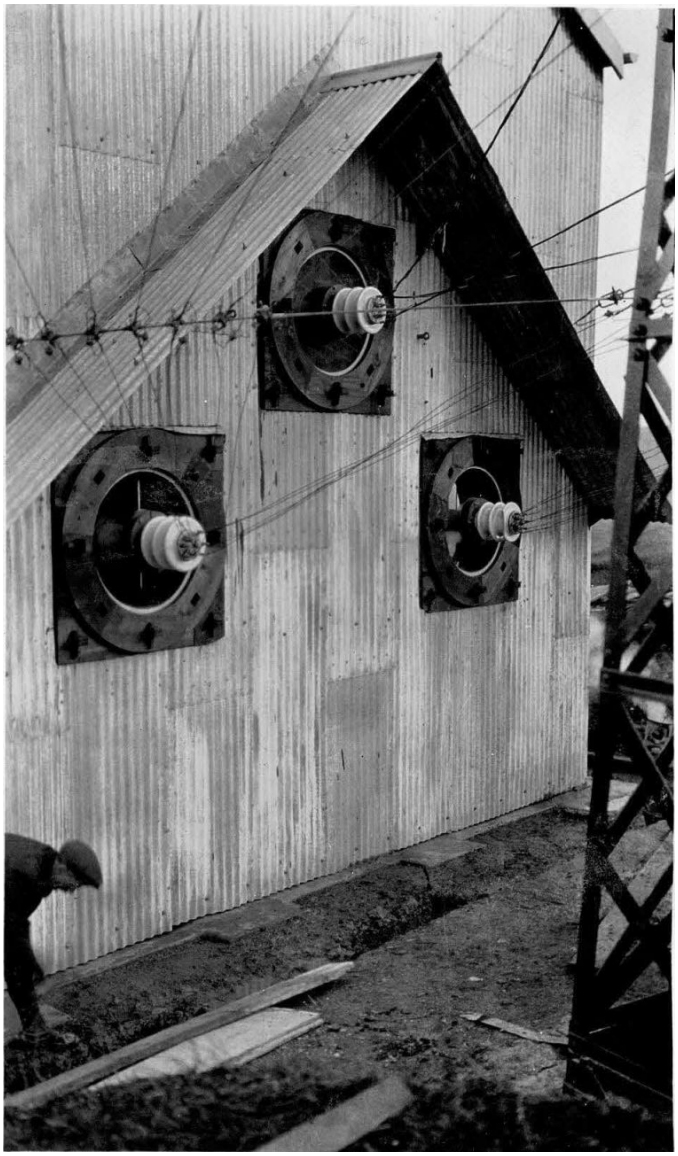
The Single ATI House

A single tuning inductor house was erected at the lower end of the hill accommodating the 1923 extension. It lies at 1040' amsl, overlooking Llyn Padarn. There are far fewer ceramic remains here today than at the upper ATI, but those that are scattered around are of the same materials. A large amount of asbestos fragments, used for internal lining, lies around in the wet conditions, rendering them relatively safe; care should be exercised by anyone visiting this specific location of the antenna site which is, in any event, a very challenging undertaking due to terrain and undergrowth.

Insulated strainer lattice masts, like those at the upper ATI were built facing the antenna, uphill, tensioning the antenna feed and counterpoise wire arrays. Small areas of remaining corrugated steel sheet set at the base (see **74**) show conclusively that its skin was of that material, and not asbestos. Again, its roof may have been asbestos, but there is no evidence of this.



79. *The lower, single ATI house for the 1923 antenna array, seen from the south. Internal dimensions 22' x 22', externally measuring, at corrugated sheets, 23½' x 23 ½'. Bodleian Special Archives MS.Photogr.c.243, photo 744/x. As for the double ATI, the feed to the radiating elements are from the three 'hatted' towers, the counterpoise wires from a single catenary strung between the two towers to the sides of the inductor house.*



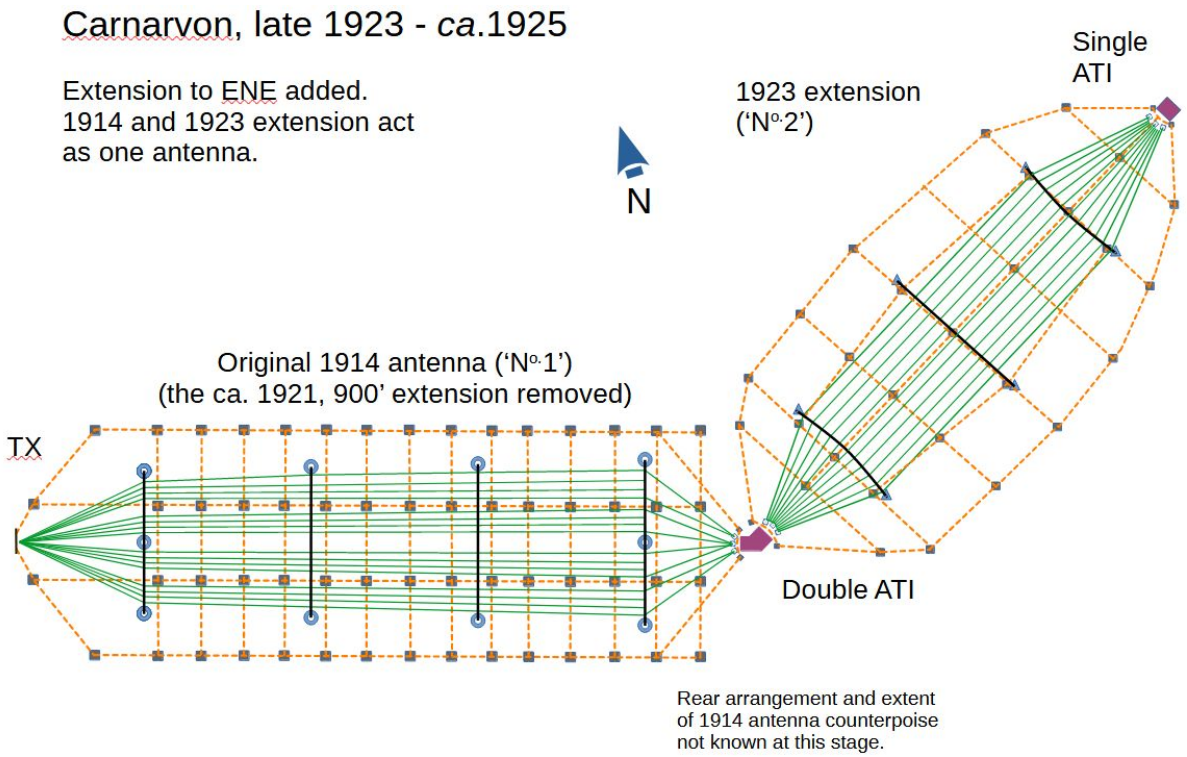
80. *Detail of antenna-facing elevation of the lower, single ATI house for the 1923 array, seen from the west. Counterpoise wires are seen feeding from a catenary between strainers on either side of the building, in turn fed from the lower two through-wall insulators. The top insulator is the feed for the radiating wires, leading to triatic wires between the lower towers uphill. The gentleman at left appears to be working on a French drain along the front of the house. There was no internal drain as in the case of the upper, double ATI house. Bodleian Special Collections, MS.Photogr.c.243, photo 746/x.*

Despite the investment in extension, Carnarvon was not able to keep up with all the demands of Empire. A report in the Friday, 2nd February 1923 edition of *The Scotsman* (p.7) tells of how the "Imperial" (British) Government asserted that Carnarvon and Leafield were "not sufficiently powerful to carry on a continuous communication with the station which was being erected in South Africa" and that a new station in "England" had been considered for this purpose.

The Antennas Split (ca. 1925).

Vyvyan (op.cit., p.67) tells us the antenna was later “split” (yet again providing no specific date) so that two transmitters could run independently. He tells us a new feeder was “run up the mountain” - a late photo discovery shows this was a twin, caged feed line run over telegraph poles, one account in the C&W archive believing it to be one of the first if not the first application of balanced feedlines. The 1923 extension in its entirety was then used as one antenna, and the 1914 antenna (without its *ca*. 1921 extension of ~500ft) as the other. The original, 1914 antenna as split now usually operated as 'GLC', not MUU as it earlier had been (see, for example, Bodleian MS.Marconi.788, item 3, internal letter of May 21, 1926, ref: XX RD/6238) - according to Vyvyan, at 9500m (32kHz) - whilst the 1923 antenna used 14000m (21kHz) though MUU could be switched onto N°. 2 antenna as well (MS.Marconi.788, item 3, internal letter of May 19, 1926, Ref.No. 20815, Woodward to Ditcham). The 1923 antenna transmissions were, confusingly, usually or always – the situation is never precisely clear – now by the callsign ‘MUU’. At some point after 1924, Hawkins considers after 1930 (pers. comm, 30/09/2024), MUU became 'GMU', bringing it into line with the standard 'G' prefix for UK stations (C&W Archive, in folder *'Concentration of Wireless Stations 1938'* via Paul M. Hawkins, examined in January and October, 1997).

The split seems to have been made within only a year or so of first operating both arrays as a single antenna. By this stage, the era of VLF commercial wireless was rapidly closing.



81. *Two arrays now transmitting independently, the upper array via a new feedline from the transmitter house. MUU transmitter could be connected to either the 1914 or the 1923 array and it may have been possible, where necessary, to operate both antennas together after the 'split' of 1925; matters are not very clear. It is also unclear whether GLC transmitter could be coupled to the 1923 array.*

At a very late stage in this study, a small projecting iron tube was noticed 3 feet to the NE from the corner seen in (**77**) of the porch surface excavation. On clearing overgrowth, this was seen to be one of two such tubes, each with a substantial copper wire with a lead metal sleeve. Initially thought to

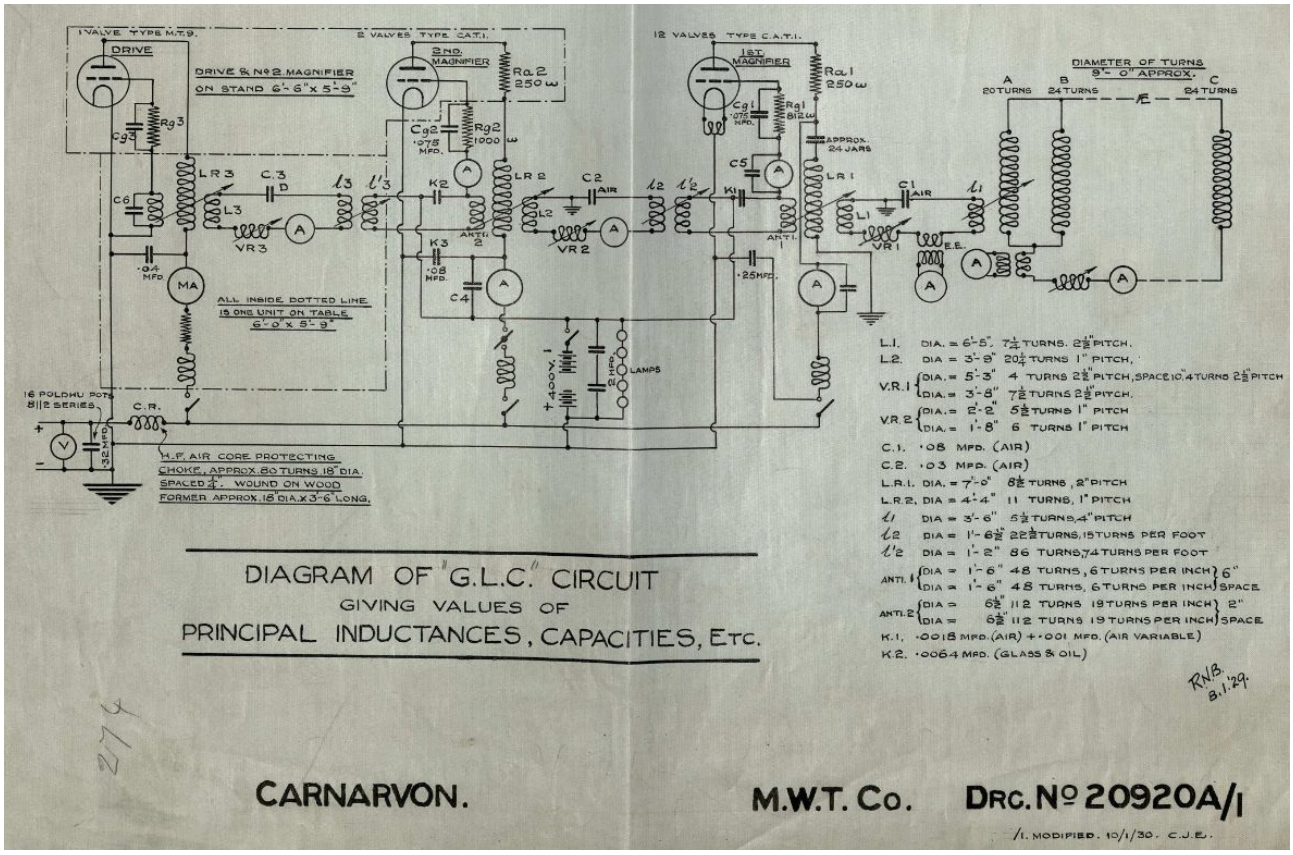
be the feedlines for the later N$^{o.}$ 2 (upper array), they may in fact be the feedlines for GLJ, because we know the N$^{o.}$2 feedlines came up the hill on telegraph poles; a single straining buckle and rod near to the double ATI building suggests it ran overground all the way to it and was not buried. Image **89** might confirm this interpretation, though the connections to GLJ are depicted on the opposite side of the building.

The concrete where the pipes were installed appeared to have been cut into and then repaired, following the installation of the tubes that carried the shallow-buried wire through the base and up into the inside of the upper antenna-facing ATI building. The copper wire remains bright on light surface cleaning, and a layer of grease, still clean 83 years after the wires were cut, seems to have been part of the cable waterproofing. The feedlines were buried at 5 inches at entry into the building base. The route beyond this depends on which antenna they actually fed, which is currently uncertain.

82. *Twin feedline entering the double ATI base, left, emerging within the building through iron tubes, right and* **83**, *below:*

84. *After a couple of days' drying, the much brighter concrete (and distortion of the outer edge of the internal drainage channel) clearly confirms the original 1923 double ATI concrete base was cut into (ca. 1925) in order to install a new feedline. Steel tubes, externally threaded, OD = 2¼", lead cable sheath diameter ca. 30mm. An additional wire (lead cable sheath diameter ca. 15mm), possibly the connection to the GLC (lower) earth screen, to the east of the porch, in the MUU (upper)-facing part of the ATI house (***85***, below), seems to have been in place from 1925. Tube (unthreaded exterior) for this cable is OD of 2½", ¼" wall thickness. The hole for the cable to emerge from the base was found, but no trace of the cable remains.*

85.



86. *The GLC circuit, signed 'R.N.B.' - presumably R.N. Barrington, 8th January 1929 (modified 10/1/30). Bodleian Special Collections, MS.Marconi.198. Note, this was the transmitter connected to the first antenna (by now, antenna circuit Nº. 1), previously – and very confusingly – operating as MUU.*

A letter of May 19, 1926 from then station Engineer-in-Chief, R.N. Barrington, mentions the use of MUU (transmitter) "on either Nº.1 aerial alone, or on Nº.1 and Nº.2 aerials", the selection being made by "remote controlled change-over switch " installed within the double ATI building (MS.Marconi.788, item 3, internal MWTC reference PJW/EWR. Ref. No. 20815). This is not perfectly clear. It might be that the wording suggests the 1914 and 1923 arrays (Nº.1 and Nº.2) could be operated not only as separate antennas as Vivian asserted, but also as a conjoined array as had earlier been the arrangement. Either that, or it meant that MUU transmitter could operate from either Nº. 1 or Nº. 2. The author currently thinks the sentence construction leads to the former interpretation being the correct one.

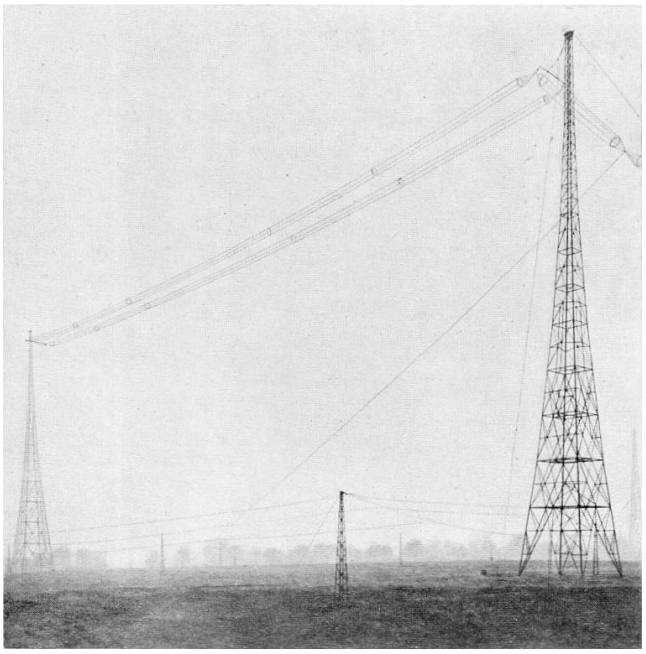
The 1925, ‘Lost’ VLF Antenna – GLJ.

According to Vyvyan, a ‘second antenna’ (strictly, a third antenna) was constructed and operated under the callsign ‘GLT’ in 1925. Williams (op.cit., p.74) writes only two sentences about this antenna, relying, as he was, on Vyvyan’s sparse account. Vyvyan asserts it used a wavelength of 7800m (38kHz) using a 40kW valve transmitter, for traffic between Spain, Egypt and Glace Bay (op.cit., p.67). It would thus have been a fairly substantial construction.

No trace of this antenna could be found, until a late request for obscure files indexed as ‘Obsolete Job Number 1040, Carnarvon Valve Troubles’ – MS.Marconi.788 (item 3) to the Marconi archive brought a staggering, 126 new pages of material. This holds detailed technical correspondence, spanning June, 1925 to March, 1927, between, amongst others, W.T. Ditcham of the Research Department at Marconi Works, Chelmsford (who was the voice for the first radiotelephony message from Europe to America in 1919; voice had been sent in the opposite direction, from Virginia to Paris, in 1915 (*Chelmsford Chronicle*, 25/1/1946, p.12), and P.J. Woodward, the then Engineer-in-Charge at Carnarvon. A smaller ‘Obsolete Job Number’ file of 28 pages – MS.Marconi.790, item 5 – contains a few of the earliest exchanges about trouble with the ‘third antenna’. The design wavelength was 8000m (37kHz) and it operated simultaneously, alongside the adjacent GLC.

The files discuss Circuits 1, 2 and 3 (i.e. antennas 1, 2 and 3) at length before, at pages 49 and 50, Woodward drew invaluable and unique diagrams of Circuits 1 and 3, making the overall arrangements clearer. Circuit 1 was the 1914, antenna, now operating from valve transmitter, GLC, though it seems MUU transmitter could be used on it also. Circuit 2 was the 1923 extension, by then operating as its own antenna, from the MUU, Alexanderson transmitter; it is unclear whether GLC could be used on N$^{o.}$2 antenna. Circuit 3 was the ‘lost’ antenna, repeatedly and unambiguously identified throughout the copious correspondence as having the callsign GLJ, *not* GLT as Vyvyan gave – a case of mistaking a ‘J’ for a ‘T’, somewhere along the line. GLJ was also valve-based.

The GLJ circuit was probably not complete until very late 1925 or early 1926, and made its first test transmissions during May, 1926. It appears to have been a ‘caged’ arrangement of several wires separated by circular spreaders. Although the support arrangements at Carnarvon are unknown, the antenna itself was probably similar or identical to the type seen at Ongar station, depicted at **87**.

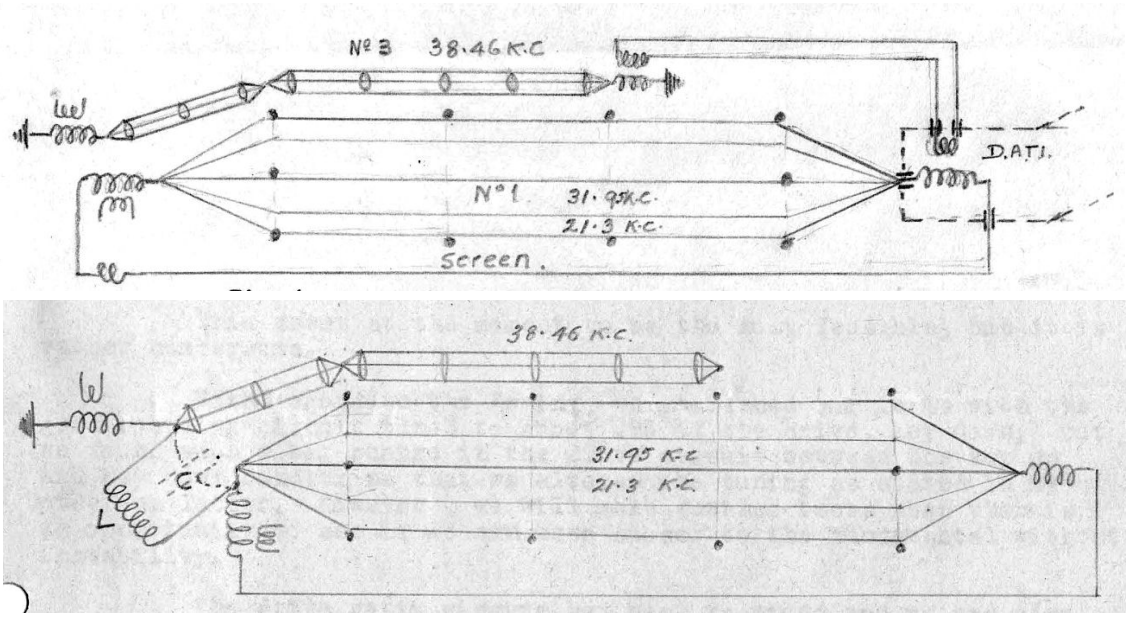


87. *Ongar (Essex) station inverted-L of caged wire design, ca. 1927. GLJ at Carnarvon seems to have been much the same design, though longer, but the support arrangements are not yet known. Promotional pamphlet in Bodleian Special Collection, MS.Marconi.199. Note earth screen beneath, held up by masts as at Carnarvon.*

The correspondence, where Woodward at Carnarvon sometimes sounds rather tested by events, tells of considerable and immediate difficulties experienced with new ('CAT 5') valve types (Bodleian MS.Marconi.790, item 5, letter of Marconi C°., internal reference PJW/EWR 20712, 10/3/1926) and strong interactions between GLJ and the other two antenna circuits. Even the wind – hardly a minor feature on a north Wales hillside – caused detuning of GLJ. A shortening of GLJ was being advised in June, 1926. By November, a lengthening was suggested. Earlier, on June 28th, after what was already months of detailed correspondence, Woodward, inundated with one proposed solution from London after another, pointedly complained to Ditcham that "although the job looks small on paper, it is, in practice, a very long one…". Woodward was looking forward to a holiday, due to start the following weekend (Bodleian MS.Marconi.788, item 3, internal letter PJW/EWR Ref. No. 20878).

The two diagrams Woodward drew were a train of thought as to fixing the difficulties; it is unclear what arrangement was finally adopted, or how long GLJ was ultimately kept in the air. A letter (internal reference H-1438, 24/11/1926, Entwistle at Marconi House to Ditcham at the Research Department, Chelmsford, MS. Marconi.788, item 3) explained that an intention, prompted by its unsatisfactory performance, to convert GLJ to short wave use for the US and south America had been abandoned in favour of its continued service at VLF to handle increased European traffic owing to the commencement of a new "Portuguese service". The situation with GLJ continued to be very fluid, with an initial pursuit of a change in wavelength to 4050m (74kHz) at the end of June 1926 being abandoned in favour of 4500m (67kHz) by the end of July, with further slight wavelength modifications up until at least November 1926 (Bodleian Special Collections MS. Marconi 788, item 3, Marconi internal references RD 6368, 30/6/1926 and PJW/EWR 20916, respectively). GLJ, with the same alignment as MUU, was precisely broadside to Portugal; alignment and directionality were now, it seems, of little concern.

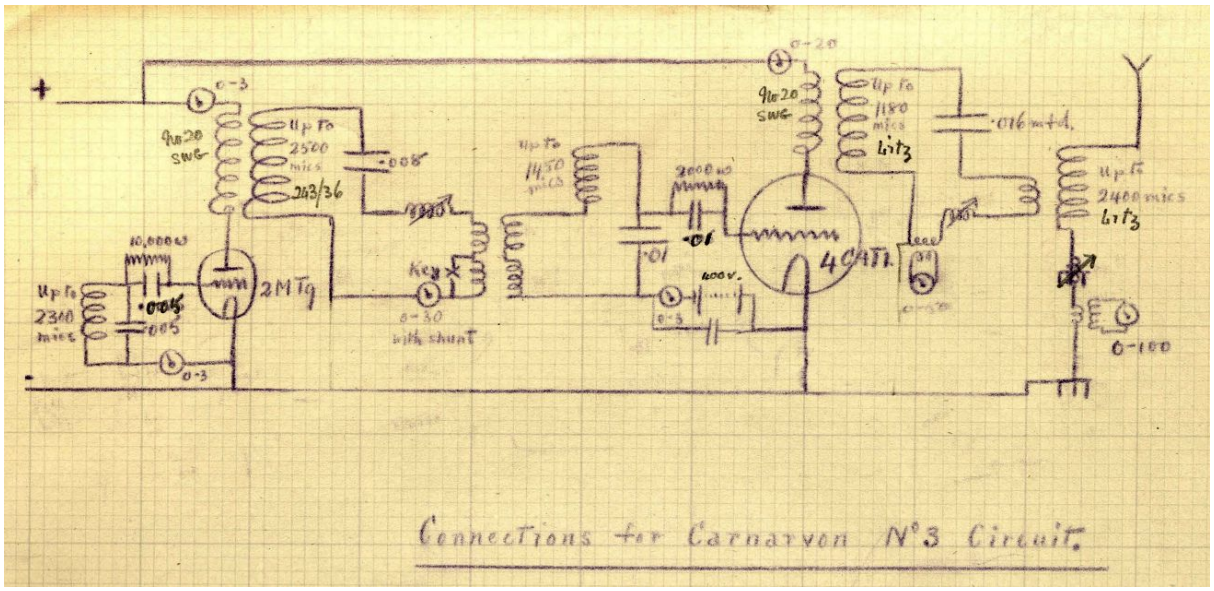
Woodward's drawings give a good indication of where to expect any mast bases for GLJ to remain relative to N°. 1's masts, but none are now evident. The aligning of the ends of GLJ, relative to the northern line of masts, might suggest that a triatic could have been run down from the mastheads, and GLJ slung from it; two images (see **90a**) found in 2024 do show arms extending to the north of at least two of the northernmost masts. These do not appear to have been present in the earlier iteration of the then MUU antenna and it may be these arms were standoffs related to GLJ's rigging.



88. P.J. *Woodward's drawings of MUU ('N°.1') and GLJ ('N°. 3') in MS.Marconi.788, item 3, letter dated May 19th, 1926, Ref.20815. Vyvan's 1933 account of GLJ's wavelength (at the time) was correct.*

The ‘orphan’ octagon inductor base close to Mast 8 (see **108**) *might*, in light of the information in MS.Marconi.790, find explanation in possibly having been erected as part of the attempt to bring matters under control between Nº.1 and GLJ. Certainly, the correspondence reveals the extent of experimentation with inductance coils and the materials and effort swung into action to make things happen during just this brief, 17 month correspondence period alone.

Woodward also drew an electrical circuit diagram for GLJ (‘No. 3 Circuit’).

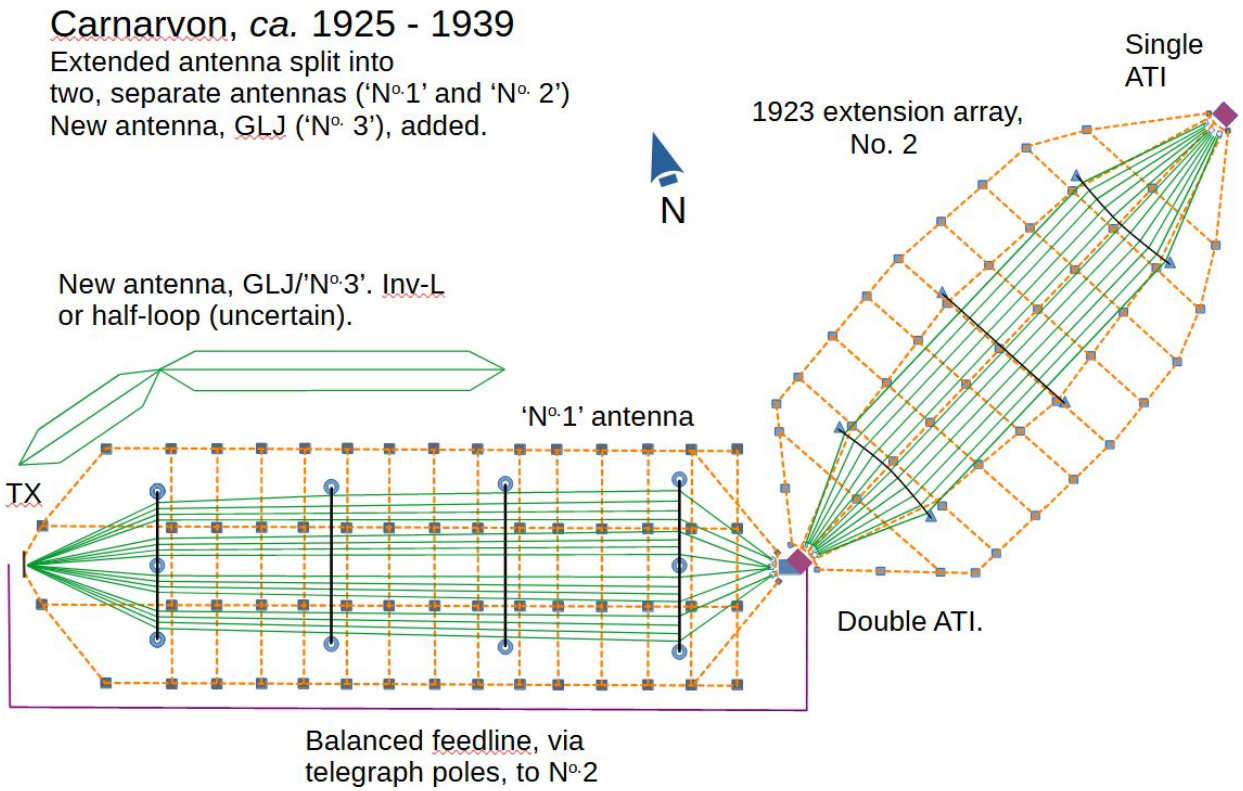


89. GLJ *circuit diagram by P.J.Woodward, Bodleian Special Collections MS.Marconi.788, item 3, collection of sketches on the same gridded paper, one bearing “Machine Shop, 13/11/1925’, all relating to Circuit Nº. 3.*

A fabulous cameo that appears in the correspondence, and which ultimately led to the resolution of the plethora problems with GLJ, is worth noting, if only for its spectacularly dangerous nature (R.W. [an error – actually R.N., confirmed in letter references of ‘RNB...’] Barrington, Engineer in Charge, Carnarvon, to Chief Communications Engineer, Radio House, February 22nd, 1927, internal reference 21212; Bodleian Special Collections MS.Marconi.788, item 3):

> ‘It has also been discovered by lifting the lids of the two .004 mfd H.F. circuit oil condensers about ½-inch, and looking into the tank whilst operating the set that severe brushing was taking place above the oil from the terminal rods to the edge of the hole in the lid through which they pass and at about 100 amperes in the circuit the condensers broke down at this place tripping the machine breakers. The voltage at 100 amperes is 30,000 volts RMS approximately.’

[Note: '0.004mfd' denotes microfarads (μF), the unit in which capacitance for wireless circuits was commonly expressed for much of the 20th century. Though a still-valid unit in suitable cases, this particular value range would now be more usually expressed as 4 nanofarads (nF) or, less often, 4000 picofarads (pF)].



90. *Schematic of all three, separately-operating antennas ('circuits') in operation at Carnarvon by around 1925. GLJ's position is based on 1926 diagrams by P.J. Woodward, which does seem to have been built as close to MUU as those suggest. Shortening and, soon afterwards, lengthening of GLJ was undertaken in order to try and tame strong interactions between it and both of the other antenna circuits. It appears that the MUU and GLC transmitters could be connected to either No. 1 or No. 2 antennas by means of remote-control switch within the double ATI building, though precise details are lacking.*

There is also, in the C&W archive, mention of a 'GNC' transmitter and that its antenna was broken at the time of noting (1930s). Nothing else is said of it and for the moment, it is unclear whether this was a typographical error as occurred with GLJ at some point, or else relates to an antenna that did exist. There is no physical evidence that points to such an antenna but, then again, neither is there for GLJ, the existence of which, however, is well-documented.

90 a. *Circa 1925 image from the Hayward collection, showing masts 1 and 4 (two leftmost, northern) with arms extending to the north. These do not appear in earlier images of this array and it may be the arms were standoffs for hanging the GLJ antenna, which is known from Woodward's drawings to have been located to the north and for which no evidence of mast bases can be found. Original taken by R.N. Barrington, then Engineer-in-Chief at Carnarvon.*

91. *A photo from Cwm y Glo, date unknown but post-mid-1923 due to the presence of the antenna extension. The image is too poor to see any real detail, especially of the lower antenna (by now, GLC).*

Well before the 1923 antenna was completed, valve transmitters capable of generating very much higher frequencies than those produced by rotating mechanical machines were rapidly taking over. Marconi had already found that short-wave radiation (at 32 metres, or 9.4MHz) offered substantial benefits in terms of range, propagation characteristics and the “one-tenth” power of very long waves needed for reliable communication (Marconi to Beatrice (later his wife) recounting a trip to Cape Verde for short wave experiments aboard *Elettra*, June 6, 1923). In *My Father, Marconi (Frederick Muller Book Co., 1962)* Degna Marconi recounts (p.239) how the benefits of short waves (SW) now evident to her father were such that a “vastly expensive” VLF station well into the process of construction in South Africa was halted and a new, SW, genuinely directive ‘beam’ antenna built in its stead. Such SW stations, of a very different design to the inverted-L, went on to form the Imperial Beam system – which of course would not have been needed, had Marconi’s claims about his ‘directional’ inverted-L antenna been true.

Had Marconi experimented with short waves a couple of years later than he did, the solar cycle minimum, where propagation at 32m becomes substantially weaker or even absent, may have led him to different conclusions about their usefulness. Doubtless, he and his engineers would have tried longer wavelengths, which suffer less during solar minima.

Directional VHF Antenna Experiments

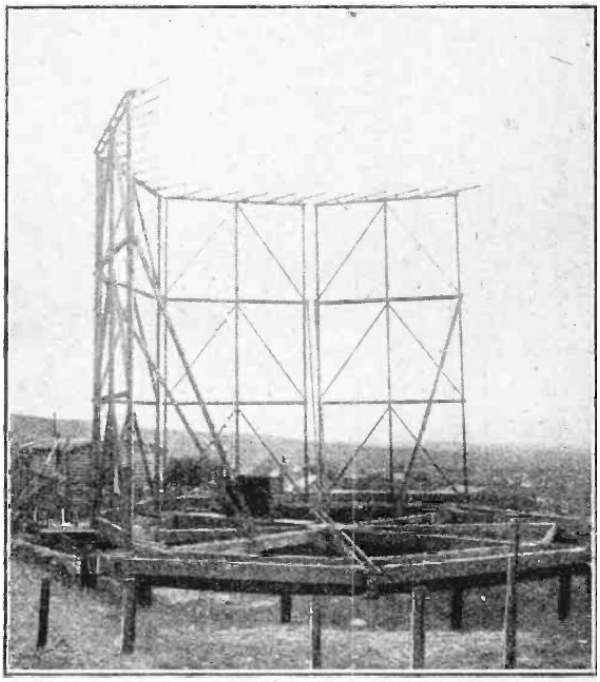
Some of the very earliest experiments with directional beam antennas took place at Carnarvon between December 1916 and September 1917, under the direction of Charles Samuel Franklin. A single photograph of such a beam showing the ¼ wave radiator at the focus of a reflector of vertical wires suspended from a timber frame, all mounted on a rudimentary, probably rotatable frame, was published in the December, 1926 edition of *The Wireless World* ('The Wireless Beam. A Note on the Work of the Pioneers', N. Wells, pp.875-876); see **92**.

As in the earlier case of tuned circuits, Marconi and his workers held a view, encouraged by the commercial advantage they felt it afforded, that directional transmissions offered a "very considerable degree of secrecy" (report sent February 1st, 1918 by Franklin to G. Marconi, MS.Marconi.232, p.14) to those who wished to use it. Whilst a directional beam would reduce the likelihood of transmissions being heard to the side and behind the beam, it would not stop anyone located generally to the front from readily intercepting the signal. Backscatter could even render the signal detectable from the rear; but they were probably unaware of that phenomenon at the time.

The depicted antenna was certainly of the general form for all the experiments involving transmissions to a mobile receiver, detailed in a lengthy report in the Marconi Archive (MS.Marconi.232). Receiving tests were undertaken along a transect (see **94**) that ran, always with a clear line-of-sight to the Carnarvon station, to determine the strength and pattern of the signal.

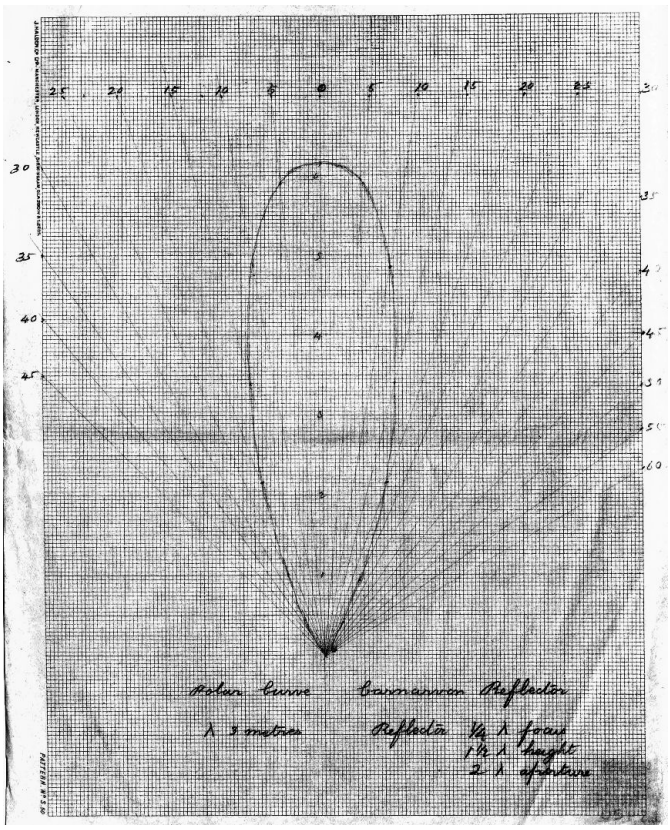
Three positions were taken up in sequence to receive: a small tower on a prominent hill opposite Caernarfon castle, a low hill – probably near Bodowen, on the Bodorgan Estate – and a clifftop location at Rhoscolyn, probably at or near a (still extant) lookout station.

Unlike the wishful thinking about the directional nature of the inverted-L, these beams did focus their energy in a very narrow beam. Following this early work, with a view to further enticing an Admiralty already impressed by the system, Franklin moved the directional VHF work to Portsmouth (Bodleian Special Collections, MS.Marconi.232).



Aerial and reflector used in beam experiments at Carnarvon, October, 1919.

92. As per original annotation, from *The Wireless World*, December 1926, p.875). The framework is of timber; the projecting top arms held the vertical reflector wires.



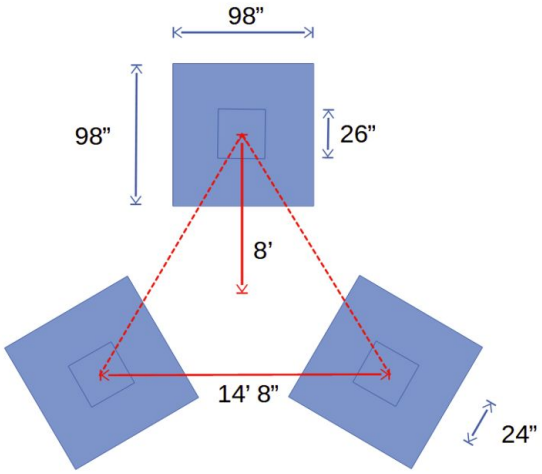
93. *Polar plot of radiation pattern from Franklin's experiments with a 3m beam transmitting antenna located near the main station buildings at Carnarvon. Bodleian Special Collections, MS.Marconi 232. Unlike the measurements of the inverted-L antenna, this result was likely reliable in depicting the very narrow radiation pattern.*

94. *Location of the three, line-of-sight mobile receiving positions during VHF beam tests. The transmitter was located at the Carnarvon station (cluster of features at lower right). Base map courtesy* Google Earth.

Bases and Anchors.

95. *Concrete baseplate mounting block (Mast 6), with 16 bolts of 2” diameter at 14.5” centres protruding 4.25” in a ring 6 feet in diameter.* 53.123082°, -4.182320°.

96. *The six, 1923 extension masts, running from the top of Cefn Du downhill towards Llanberis, were of very different construction to the 1914 antenna, each being a three-cornered lattice, 400’ high. Each of the three concrete bases is ~98” (~8’) on a side, of raised tops with a 26”x24” concrete depression made by a mast foot plate in the centre, where eight bolts of ¾” diameter protrude 2” above the concrete. Each base has centres separated by 14’8”.* 53.121808°, -4.173193°.



97. *Schematic of 400’ lattice mast base blocks. Measurements taken from Mast 11 base.* **97a**, *right: Mast 12 bases, seen in true vertical from a drone.*

98. *Bolts for attaching one of the three feet (Mast 12, foot A) of the 1923 extension masts. Central depression in base 26” x 24”. This specific foot has the normal eight securing bolts set into the concrete, but also two, slightly smaller bolts at the inner side. All other pads show impressions of such bolts, which were presumably fixtures on the bottom metalwork of the mast that became fast in what must have been somewhat unset concrete at that point.*

98a. *A pristinely-preserved 1923/4 extension footpad, one of three per lattice mast (here, mast 13, shortly later 17), showing the baseplate securing threaded studs and, either side of each, negative hexagonal nut impressions (blue), presumably made by nuts on the underside of the baseplate. Two of those nuts remain in situ, denoted by ‘P’ (‘present’). Note the positive and negative impressions in the densely-matted grass root and soil cover.*

99. *Profile of a 1923 lattice mast base block (one of three per 3-sided mast). As is the case for most of the concrete structures, the raised top surface, for drainage away from the metalwork, was evidently laid separately to the main block, and appears to be fairly weak in comparison. The studs, however, ran deep into the main block. Note horizontal shuttering impressions. Mast 14, footpad C,* 53.123037°, -4.169589°. ***Inset, top:*** *1915 installation of mast plate at Abu Sueir, Egypt, prior to "grouting and plastering", clearly a generic and widely used Marconi site construction method, shown completed at* ***inset, lower*** *(MS.Marconi.219).*

100. *Detail of 1923 lattice mast base arrangements from a larger photograph (MS.Photogr.c.243, photo 729/x) following Mast 13's collapse. The hand-drawn labelling is contrary to the foot pad labelling scheme indicated by MS.Photogr.c.243, photo 734/x (see mast identification graphic at p.10,* based on information in original caption for **104***), and is not considered to be the general identification scheme used across the site.*

101. *Single, 1923 mast stay anchor 14A, a form used earlier, e.g. in 1915, at Abu Sueir, Egypt (inset, MS.Marconi.219) and for MUU in 1914 (see* **120***). All but two 1923 anchors still have two copper or brass screws of ¼" shank, 7/16" single slot head, one behind the other along the centreline towards the mast, cemented into the block, and protruding slightly (see* **102***, below). A smaller anchor, probably for backstaying a counterpoise mast lower down the hill retains the only known intact copper earthing strip, secured by slotted-head copper screws, explaining their presence on the other anchors.* 53.122647°, -4.170550°.

102 (left): *Slotted, probably copper screw that once secured a copper earthing strip across the top of a 1923 stay anchor that ran to ground.*

102a: *At the centre rear of mast anchor 13a (17a), remains of the stay grounding strap, 54mm wide, were discovered. The metal, magnetic, is 'Copperweld' - steel with a bonded coating of copper, widely used for grounding purposes from 1915 onwards.*

The three anchors for each of the 1923 extension masts, lying 300' from the masts, consisted of an embedded steel anchor plate, with two 'U'-bolts either side – all cut back to the concrete when the structures were demolished. The anchor beneath blockhouse 5, and that at the easternmost extremity of the antenna, is a double anchor, top surfaces gently sloping towards the centre.

103, above: *double stay anchor (15C, long face to left and 16B, long face at foreground) at eastern, lowest end of the 1923 array. Its construction is seen in* **104**, *below (Marconi. Photogr. c. 243, image 734/x), the labelling allowing full understanding of the numbering system for the three anchor points of the entire array.* 53.125478°, -4.166813° Lower centre, pointed end at **104** is lower left in **103**.

104. As per label. Bodleian Special Collections, MS.Photogr.c.243, photo 734/x.

105. A clear example of a 1923 counterpoise lattice mast base, with remnant steelwork. Concrete base of 4'x4', lattice of sides 32" x 32".

The ~500ft rearwards, linear extension of ca. 1921 to the original 1914 antenna needed two large lattice pylons. Their height is not given anywhere. Their size, being 60' on a side, was probably sufficient to ensure self-support under antenna wire strain and there is no evidence of anchoring points for them. Each of the four foot bases of concrete is ~8½' square (varying slightly, between 101¼" and 103 ½"), the inner depression, about 2" deep, where the foot plate of each corner of the mast was anchored, measuring between 42½" and 44" square, and thus the foot plate probably 3½' square. The pylon was secured by four, 1.5" diameter threaded bolts, their centres 27" apart, set deep into the concrete, projecting between 7" and 9½" above the depressed concrete surface. No photograph or description of these pylons is known, but they were almost certainly tapering in form (see **58**).

106. *One of four ~8 ½' concrete base feet for one of two* ca.*1921 extension pylons* (53.120347°, -4.175167°), *each* ***pylon*** *centre separated by 600'. Each of the four* ***footplates*** *of each* ***pylon*** *was separated by 60'. At the lower (southerly) mast, the NE corner base had to be installed on what was apparently boggy or otherwise difficult ground, with bolts emerging from a concrete base in a deep excavation to reach firmer ground – see* **107**.

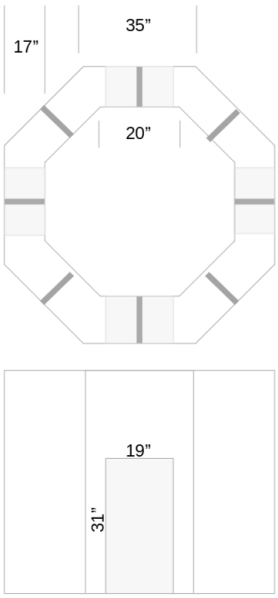
107. Ca.1921 extension pylon ‘A’, footpad ‘C’. 53.122060°, -4.174204°

108 (right). Octagonal base, which once supported an inductor. Its position, to the immediate west of Mast 7, is unusual. Its form and tracks leading to it suggest it was present from early on. Roughly at mid-point of the MUU array, it is thought most likely to have been associated with the grounding system.

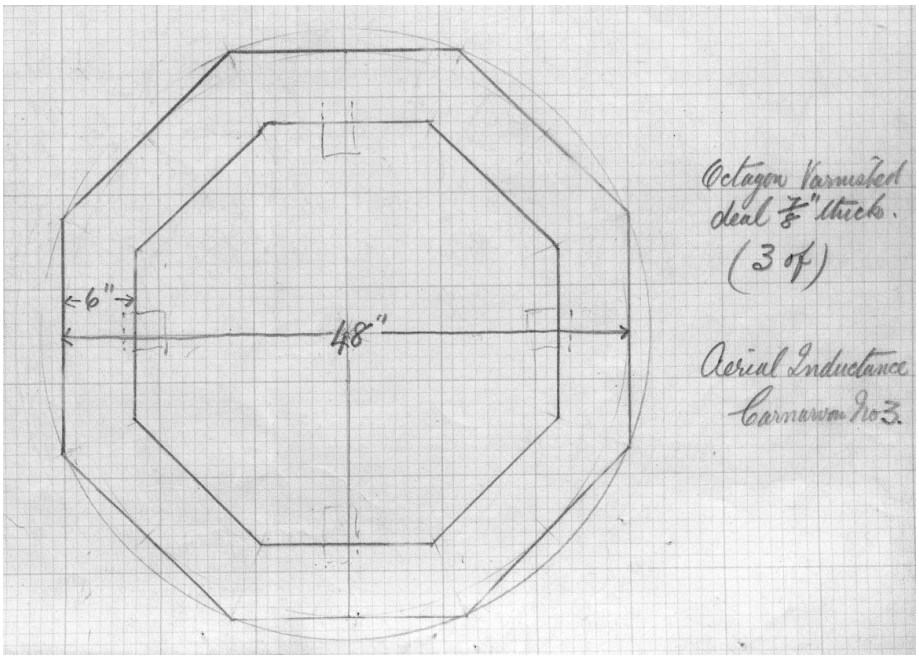
53.121591°, -4.183283°

108a, left. Octagonal inductor at VLF station, SAQ, Sweden, serving to match the antenna radiator wires seen leading down from the support towers at centre right. Image courtesy Eric P. Dollard. Also see rear cover for an image of one of Carnarvon’s inductors.

26 yards to the west of the third, southern antenna mast base (Mast 7), lies an ‘orphaned’ octagonal concrete base of initially obscure function. This has openings of 31” x 19” in four sides, with narrow slots of 17”(l) x 2 ½”(w) x 1¼” (depth), one with a timber former still in place, at the top centre of each face. Small, approximately 3/8” diameter bolts protrude ¾” above the top surface perimeter. Vertical timber shuttering impressions reveal the construction method. A seemingly identical base type is seen at Marion, MA in the United States, but erected using horizontal shuttering. Late in this study, it became clear from similar structures at SAQ station (Grimeton, Sweden) that these were bases for large inductors. Tubular (not rod-type) ceramic insulator fragments of brown glazing lie around the base.



109. *Octagonal inductor base dimensions. Top external diameter, is 7 feet. Outer bolts on top, to secure the inductor frame, form a diameter of 73½", inner bolts a diameter of 59".*



110. *Octagonal <u>former</u> (not base) specifications for (internal) inductors to be fitted as part of attempts to control antenna number 3 – GLJ. At 48", this was smaller than the inductor fitted for the (external) orphan base, which was about 6 feet (73½" outer bolt to outer bolt diameter). Bodleian Special Collections, MS.Marconi.788, item 3, November 1925.*

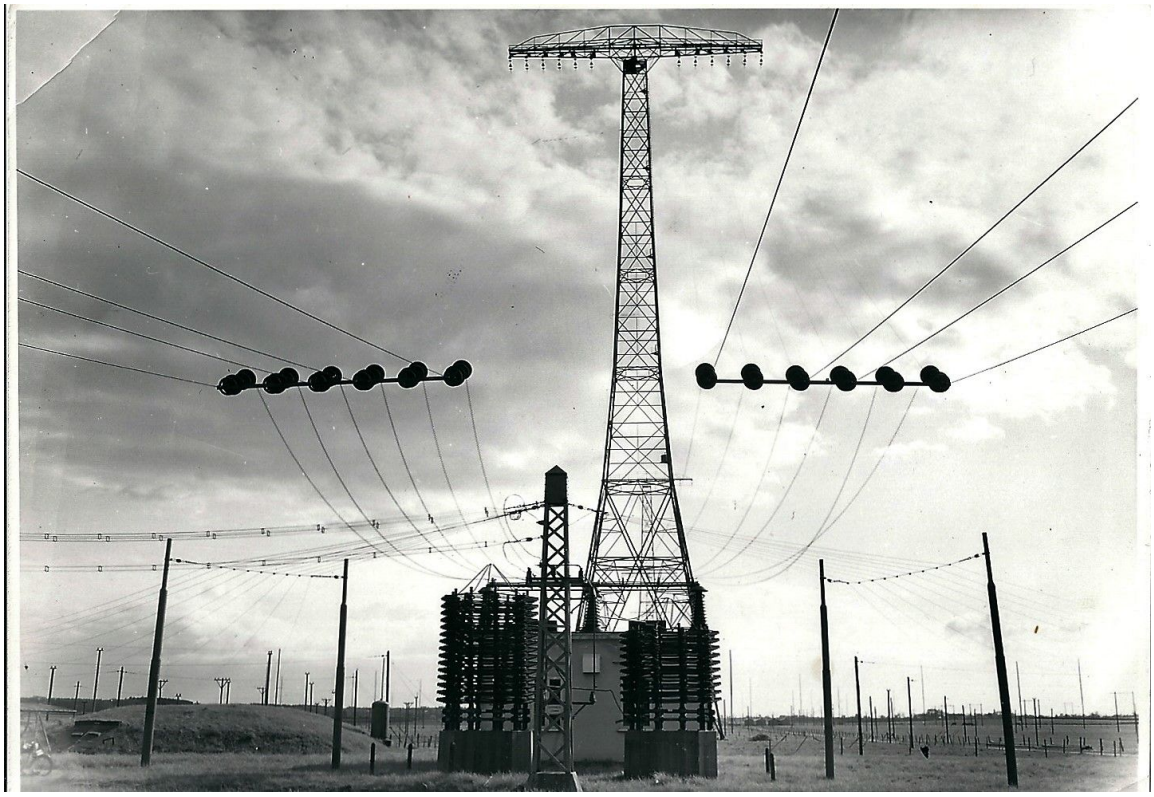
111. *Brown-glazed ceramic insulators found lying next to the octagonal concrete base.*

112. *Other than the use of horizontal shuttering to construct it, an apparently identical octagonal inductor base at the Marconi station of Marion, MA, USA. Courtesy and © 2008, M. Howells* via *Sippican Lands Trust.*

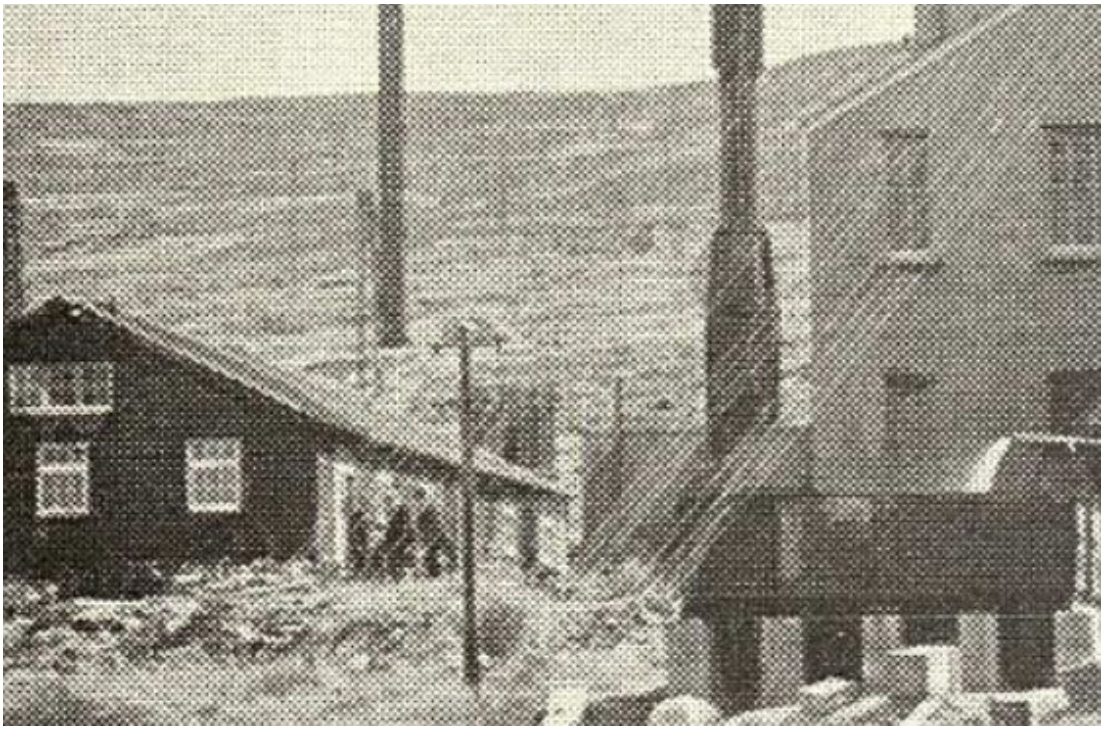
113. *Octagonal inductor base with no side openings at Bolinas, CA, USA. Image courtesy California Historical Radio Society.*

Five other octagonal bases exist at Carnarvon, all of them to the immediate east of the transmitter house. These have either one or no apertures. All seem to have supported inductors. One octagonal base lies, tipped on its side, near to the SE corner of the transmitter house.

114. *Octagonal inductor bases to the north of the transmitter house (on domestic land, access by kind consent of the occupiers). The nearest base, far right, is seen in a poor photo to support an inductor (see* **116***), and thus predates the 1925, GLJ 'third' antenna.*



115. *Long a source of head-scratching, the role of octagonal bases at several Marconi stations across the world became starkly clear on discovery of still-active inductors sitting atop similar bases – with no side portals, as in Bolinas – at SAQ, Grimeton, Sweden. Image SAQ0002, courtesy Alexander Association.*



116. *Detail from a larger, poor quality image that nevertheless distinctly shows (centre, just behind and to right of the telegraph-type pole), one of seemingly two earth system tuning inductors per side of the transmitter hall at the position of the octagonal base in foreground in* **114**. *Bodleian Special Collections MS.Marconi.198. See also rear cover image, discovered in 2024, for much better detail of the opposite side inductor.*

Small, quite roughly-made concrete anchors with ‘D’-rings are found at the end of trackbeds near the *ca*. 1921 antenna extension. Whilst practically all concrete bases had their attachment points cut and removed when the site was cleared, one anchor ‘D’-ring attachment point was found cut, but with a pulley with a very narrow running groove, presumably for a fairly narrow wire, several large, interconnected ‘D’-rings and a chain still in place. This was lightly excavated to reveal the detail (measuring tape, for scale, open to just over 2’). The anchors may have been back stays for the counterpoise towers, countering the pull of the counterpoise wire, but much remains to be understood. A similar pulley, probably widely used across the site, was captured at the very corner of photo P. 2093 in MS.Photogr.c.243, date not given but probably 1918.

117. *Pulley, attached to a series of shackles and a substantial chain still in position next to a base with a cut loop attachment, seemingly forgotten during salvage. A similar, but not identical pulley is seen in Bodleian Archive MS.Photogr.243, photo P.2093 (inset detail, top right). Its purpose in relation to the 1923 antenna is not yet certain, but initially appears to have been related to backstaying of the elevated counterpoise masts. Pulley wheel = 8” diameter, clamp body 1 ¾” thick, top running width 27mm, inner running width 9mm, running groove depth ¾”. Shackles 9½ height, 2 ½” inside width, 5” external width, securing pin 2” diameter head, ¾” central hole.* 53.120944°, -4.172144°.

Across or near to the trackway, seen at two points at the summit of Cefn Du, small rectangular concrete bases with thick iron bands, with one securing bolt having a wide copper earthing strap, are found. The purpose of these was obscure, until a photograph of the summit of Cefn Du in 1923 was discovered. This seems to show a small lattice mast positioned at the location of the base. This was reinforced by the finding of broken white porcelain insulators around that base.

119, above**.**

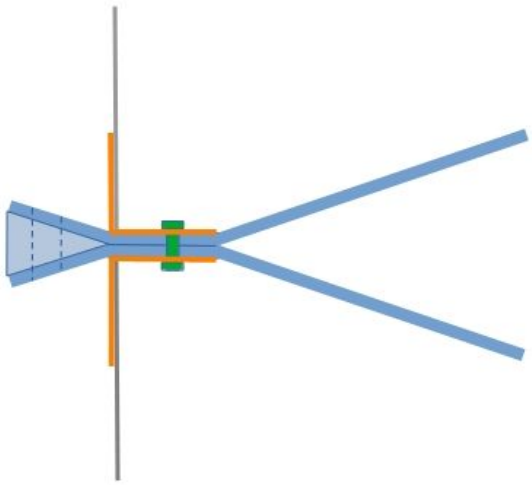
118, left, at 53.121666°. -4.172803°. *Near trackways, seen at three points at the summit of Cefn Du, small concrete bases with thick iron bands, two having a wide copper earthing strap fixed to a bolt, are found. These were bases for short lattice masts with a sharply pyramidal shape, probably related to the counterpoise system. Similar masts nearby are seen in photograph* ***65*** *to have a square section. Work to elucidate the distinction between the two types is continuing. The earth strap depicted at* **119** *is ~265' to the NW of Mast 11, at* 53.123509°, -4.175266°. *The earth strap is lost or only small fragments remain for the other bases of this kind.*

120. *Anchor blocks are located to the north and south, opposite each pair of support masts for the 1914 antenna. They all have a (now) cut, substantial loop attachment. The purpose is not known with certainty, but would appear to be either additional head-straining stay anchors, or for tensioning triatic steel ropes between the mast heads. 138" wide along rear; 82", 10° sloping rear length, ~2' long 43½° sloping antenna-facing side. Southern boundary, between mast anchors 7A and 7D, at* 53.121199°, -4.183082°.

121. *In this case, anchoring, probably of a small lattice mast, was more readily achieved by fixing an eye bolt to a conveniently-located, glacially-deposited rock.* 53.121644°, -4.176221°.

122. *One of numerous eyed stay anchoring points found across both the 1914 and 1923 sites, in this example, with a rare and good condition shackle still attached. Only one is typically found next to counterpoise elevating masts, always at 9 yards' distance – a useful fact that allowed several overgrown lattice bases to be found that otherwise would not have been.* 53.123447°, -4.168506°

123, right. *A late visit to anchor 4B revealed that it has broken apart, revealing how the steelwork for the stay attachment points was arranged. The system was much the same as that seen in the photograph of the double 1923 anchor being built, except with two splayed bars emerging from the concrete (long ago cut away), rather than a straight bar. Angle iron 4"x4". The two bars bolted between the angle iron diverge from one another into the concrete, and presumably had connecting bars or rods deeper within, to increase 'drag'.* **124, below:** *schematic of fixing, concrete outer face to left.*



125. *Entirely grassed-over when discovered, surface clearing revealed a large concrete base with corner bolts, iron spacers and two trackway rails protruding, leaning slightly towards the south-west. Thought to be a trackway winder base serving a trackway running downhill to the west, to a quarrying area behind the 1914 upper masts. Located immediately to the NE of 1921 extension, northern Pylon A.* 53.123001°, -4.171694°.

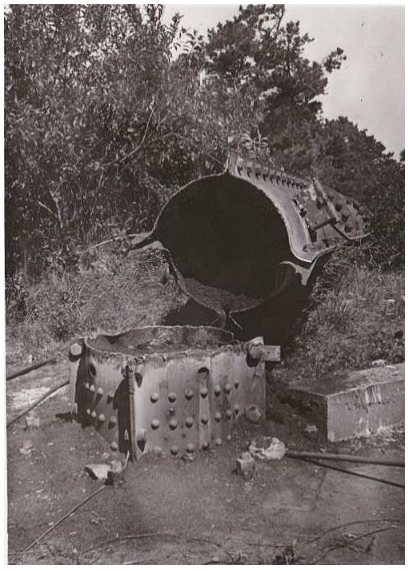
126. *Rough concrete base lying near top of incline to lower 1923 extension site. Surface cleaning revealed that it incorporates substantial ¾" bolts and impression of a machine base. It is thought to be the base of the incline brake pulleys. Note the remains of a ATI through-wall insulator, probably brought up from the single ATI at the foot of the incline during salvage operations in 1939.* 53.123140°, -4.171421°

127. *Deeply-socketed, small concrete base with four bolts. This lies at the top northern edge of the 1923 extension inclined trackway leading to the lower reaches of the site. It was not deeply-set in the ground and is quite loose now. It may have been a points or other trackway-related feature. Bolts separated by 14" x 9". Socket aperture = 9½" x 6¾" at top, 8½" x 4 ½" at bottom; 3" deep.*

53.123140°, -4.171421°

128. *Small concrete base with central loop and two iron rings affixed, located 15 yards NE of Mast 16's base. It may have been related to triatic raising/lowering.*

53.124737°, -4.166488°



129. *Felled four-section mast, usefully showing the fairly thin steel used for such supports, at Chatham, MA, USA. 1954. © Chatham Marconi Maritime Center,* via *Ed Moxon.*

130. ‘L’-section steel hammered into the ground, with shackle attached. There are a couple of these around the site, their exact purpose unknown. This example lies adjacent to anchor 6A for the 1914 antenna.

53.122656°, -4.183159°

131. Stonework incline, half-way down the centre of the 1923 site. 53.124441°, -4.168417°.

132. *One of several remaining 1914 boundary fence posts and strainers, this at the upper northern end of the 1914 site. Upright post 4' above ground level, post 42mm x 42mm, stay 35 x 35mm; 7 x strainers, separated by 8".*

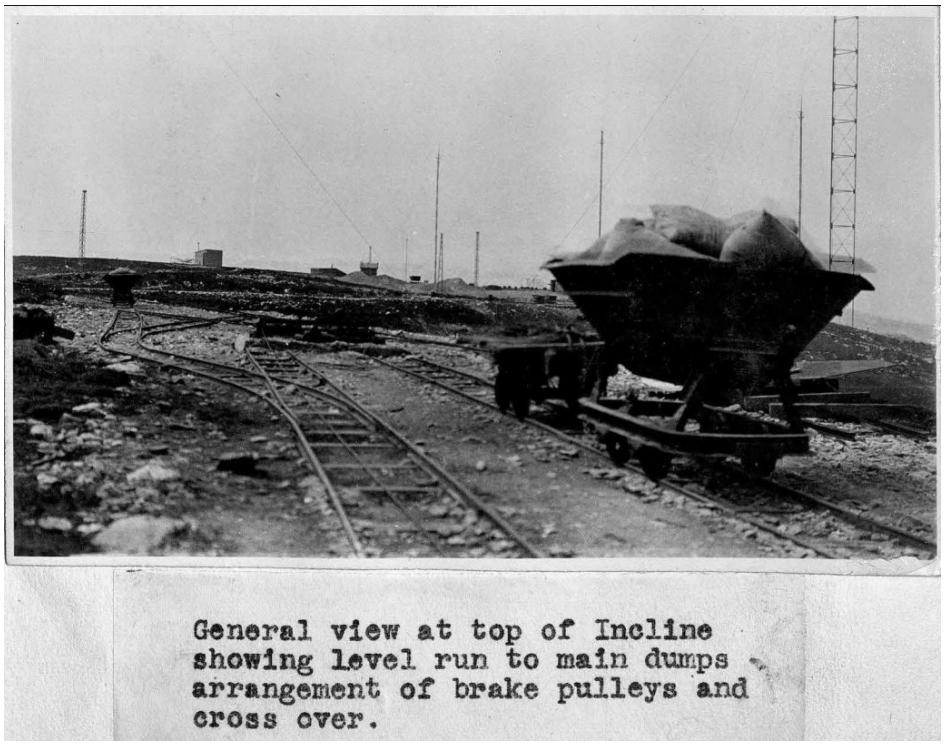
53.123202°, -4.179101°

133. *Corner bracket and ground bolt for securing a small shed seen at this position, near blockhouse 5, in the Marconi archive MS. Photogr. c. 244, photo 737/x (see* **65***). Trowel blade = 6"/150mm; 53.122301°, -4.173870°*

134. *An anchor-to-two-stay attachment plate. The top hole bolted to the loop on the anchor, the lower holes, one with a bolt still in position, each attached a stay wire. This was found near the wall and below blockhouse 5 on the upper part of the 1923 extension site. It may have been one of the main anchor attachment plates. Found as bolt surface protrusion, at* 53.122857°, -4.173596°.

135. *Glacial boulders reduced to trackway ballast on the spot. 53.121906°, -4.176516° (nearest pile)*

It is as well to include at the end of this section a few images of trackways and so on, that are well worth examining.



136. *As per caption. The 1921 extension pylons would be taken in by this view of the busy area near the summit of Cefn Du (approx. 53.123101°, -4.171513°), but have clearly already been removed. June 1923. Bodleian Special Collections MS.Photogr.c.243, photo 735/x.*

137. *Along the incline built to the lower reaches of the extension. Mast 16 (the lowest, easternmost) is in the background, with a stay cable for Mast 14 across the top half of the scene. Note the incline wire rope rollers. The gentleman, who appears in the photograph at **138** and from his clothing, clearly not working on the masts, may be a manager or owner of Francis Morton and Cº., who erected the masts, or a Marconi engineer. January 1924. Bodleian Special Collections MS.Photogr.c.243, photo 720/x.*

138. *Tensioning of one of the stay cables using rods to adjust the large threaded turnbuckles. Probably Mast 15, anchor A. Grounding connections and straps are not installed as yet in this photograph of January, 1924. Bodleian Special Collections MS.Photogr.c.243, photo 715/x.*

139. *The extensive trackway for distribution of construction material, near Cefn Du summit, somewhat to the south of the photograph at 136. The incline down to the majority of the extension site lies directly behind the gentleman, as does the very-nearly completed Mast 15. Mast 14 at extreme right. The incline brake pulleys are seen between the track crossover. The flat saddle in the mountains at centre left is the Mynydd Llandegai and Penrhyn slate quarry area. Bodleian Special Collections MS.Photogr.c.243, photo 710/x dated January 1924.*

Military Protection

Carnarvon was taken over by the Admiralty at the outbreak of the First World War. Britain was worried about its undersea, cabled lines of communication being cut – concerns no doubt considerably fuelled by the fact that Britain had itself quickly moved to cut German cables.

A useful summary of the situation is found in *The New York Times* of 1st September, 1914:

ENGLAND SEIZES RADIO STATIONS Marconi Plants at Towyn, Poldhu, and Carnarvon, Wales, for Use in War.

THREE-MILE LIMIT IMPOSED

Merchant Ships Forbidden to Send Messages When Near the British Coast.

AGREE WITH UNITED STATES

Germany and England Assent to Code Dispatches from Here Under Censorship.

The British Government has commandeered the three high-powered wireless telegraph stations at Poldhu, Towyn. and Carnarvon, in Wales, and has made an emergency war ruling that no merchant vessel carrying wireless apparatus may send messages while within three stiles of the English coast, according to information received yesterday by E. J. Nally, Vice President and General Manager of the Marconi Wireless Telegraph Company of America, which has its American offices in the Woolworth Building.

“I have just been notified that the English have taken over full control of these stations and, in addition, have commandeered our station at Clilfden, Ireland, which communicates with Glace Bay, Nova Scotia, for part-time use by the British Admiralty.” Mt. Nally said. Our company will be allowed to operate the Clifden-Glace Bay circuit during certain hours for the transmission of censored commercial or other messages, but we will be unable to use the stations in Wales until further notice. These stations were completed only a short time ago and were to have been opened to the public on Sept. 1, the American stations in the circuit being at Belmar and New Brunswick, N. J.”

Mr. Nally said the control of the wireless stations in Wales, with their powerful sending apparatus, would enable the Admiralty to keep in constant communication with British navy vessels at any point within 3,000 miles of Wales. He also said he had received information that the British Government had demanded the exclusive service of 150 of the company’s wireless operators who

were employed at the Welsh stations. These would be placed at the Welsh and other Government-controlled stations and aboard English battleships.

It is said that the order forbidding merchant vessels if use their wireless instruments near England is made to avert the possibility of official messages becoming confused with others in transmission. It is reported that in several instances the British authorities have destroyed wireless outfits on ships coming into English ports and this measure may be taken in every instance in which merchant vessels ignore the three-mile ruling.

Became of the unexpected use to which the Welsh stations are to be put, the Marconi company is planning to use the new stations in New Jersey for communication directly with San Francisco and from there to Honolulu.

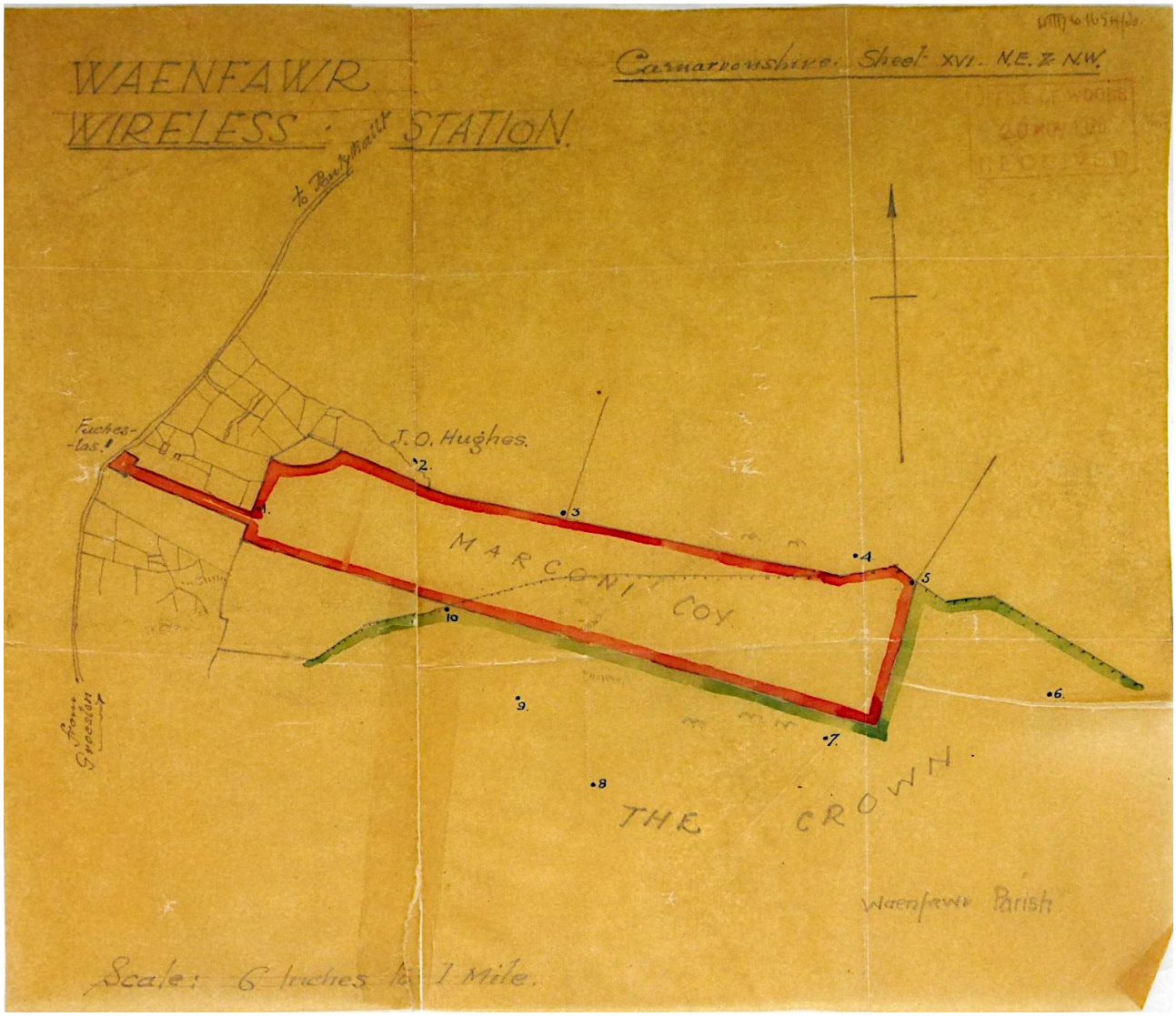
“The apparatus is being tested out for this long-range at present.” Mr. Nelly said. “and we expect to open this service for the public on Sept. 20, when we shall hold opening ceremonies at San Francisco, Marshall and Bolinas, the California stations and in Honolulu. The stations in California have been to communication with Honolulu. Probably we will be able to send messages via the New Jersey stations directly to the Norwegian Government’s Station at Scavenger [sic], Norway, and tests for this circuit are now being made.

Previous to the commandeering of the Marconi stations in Wales, Mr. Nally said, the British Admiralty had been sending coded messages through Clifden to Glace Bay. Germany, too, had been able to keep in touch with her navy at long range through the powerful station of the Telefunken company at Nauen, ten miles from Berlin, which communicated directly with Sayville

L. I.

From military regiment records, it is known that the entire Carnarvon wireless site, a strategically crucial means of communication with ships and abroad, was guarded during the First World War by N°. 1 Defence Company 6th RWF (Defences), consisting initially of 3 officers and 117 other ranks, who occupied a total of ten blockhouses, each with commanding views from around the perimeter of the site.

Early on, newspapers alerted the local communities to be on the lookout for suspicious persons and activity near the stations, because “the Germans certainly didn’t underestimate the importance” of those facilities (*Y Goleuad*, 23/10/1914, p.4).



140. *Map of the Marconi wireless site, showing numbered positions of all ten blockhouses. Thanks to members of the Great War Forum, the source archive appears to be The National Archives, Kew, CRES 49/954. The drawing date is being investigated, but the extent of Marconi’s boundary (red) would appear to indicate it was created either prior to the station being built, or not later than about 1923. The emphasis on blockhouses also suggests a date around the onset of WW1.*

141. *Remains of blockhouse number 5 (NPRN 505602), visible from many miles around atop Cefn Du. It is known locally as 'Cwt Bombs', with both live and spent .303 bullets reportedly found there as late as the 1970s. In a 2007 survey by OA North, this building was utterly misinterpreted as related to a 'radar station'. OA North could not provide evidence for the claim, and accepted what they describe as a "probable" misinterpretation (OA North to Rowlands, pers.comm, 25/8/2022). The building's narrative, with reference to earlier 'official' records is considered in depth at Appendix IV.*

142. *Interior of blockhouse 5, looking NE from the entrance.*

143. *Blockhouse 2, photographed in 1988, when the raised stonework trackbeds built to transport materials were clear of plant growth. The track going uphill to the right continues to blockhouses 3, 4, 5 and 6. By 2022, undergrowth has rendered invisible that which was, 34 years earlier, very clear. Image: Plate 6 in Gwynedd Archaeological Trust's Report 1302, March 2016, p.88. By kind permission of and © GAT.*

In terms of who was guarding Marconi Waenfawr the RWF 6th Bn. TF Association Minutes (at Caernarfon County Archives, not examined in person but kindly provided by the dedicated and skilful contributors to *Great War Forum*, online) provides some information:

Minutes for **6 11 1914:**

"No 1 Defence Company 6th RWF (Defences) stationed at Waunfawr. 3 Officers, 117 OR."

4 12 1914: National Reserves.

Correspondence received from C O , Chester.

"Please enrol another half company National Reserves, 1 Officer, 59 men making three and a half companies in all"

Major Sir T Neave, Bart, Commanding No 2 Coy had been asked to recommend a suitable National Reserve Officer and carry out the enlistment of the 59 men. He reported by letter that the General Staff Office at Chester requested a highly capable Officer at Conwy Bridge to take charge. He also intimated that there had been a great deal of 'weeding out' carried out in the other 3 companies in

order to uphold their reputation. He had no National Reserve Officer to recommend and recommended that suitable NCOs be promoted. He recommends one of the following. QMS Hammond, Barracks, C'von. Col Sgt George Green, No 2 Def Coy. Sgt J J Knight of No 1 Coy (under Captain Breeze)

Letter from Captain C E Breeze, commanding No 1 Coy, 6th RWF, Waenfawr. He is awaiting transfer to the Welsh Army Corps. He recommends Sgt J J Knight for promotion. He also recommends Lts O T Evans and J L Mayger for promotion.

Motion carried 1) that QM J T Hammond be recommended for commission and 2) should there be further vacancies for officers in the National Reserve Coys then QSM Green and Sgt J J Knight be submitted for appointments to 2nd Lts."

18 12 1914:

"Accommodation at Waenfawr. Contract arranged for hutting accommodation with Messrs Jones Bros, Bontnewydd, specified time for completion 5 weeks minimum, 17 weeks maximum.

Motion passed that Lt O T(or F?) Evans be recommended for promotion to Captain, No 1 Coy, Defences and Sgt J J Knight be recommended for Lt in that company.

Lt J L Mayger, No 1 Coy 6rth RWF National Reserves has applied for transfer to 6th Reserve Bn. Committee recommends Mr Ralph Fisher, Llandudno National Reserve for commission to No 1 Coy."

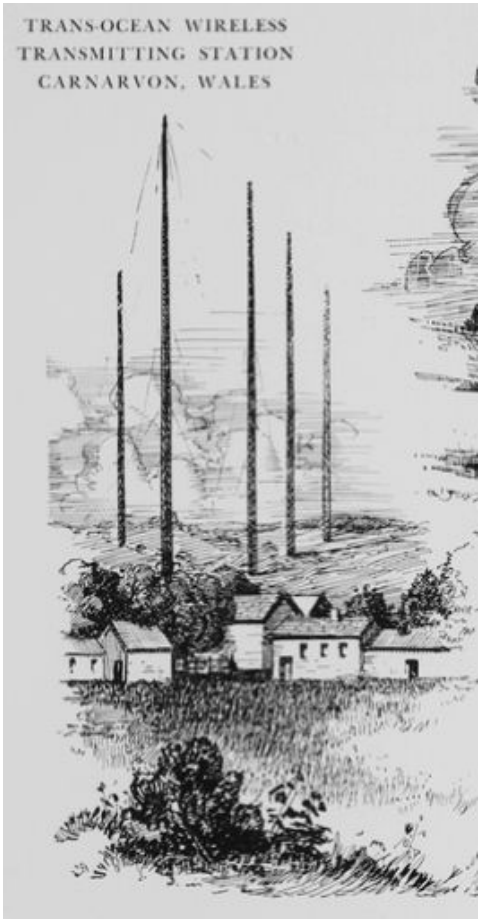
The men received their initial numbers from the 6th Bn RWF number sequence. When the unit was designated as No 1 Supernumerary Coy they were renumbered to 5 digit numbers starting with 20xxx and then in April 1916 when the RDF was formed they became 326th Coy, RDF with RDF numbers ranging from roughly 19450 to 19579.

The Wales-Australia ‘First’

Carnarvon’s much-celebrated achievement was its part in the first direct wireless message between Wales (in true imperialistic style, given in contemporary accounts as ‘England’) and Australia. It took place on 22nd September, 1918. Every year for many years, the Dragon Amateur Radio Club has set-up a commemorative station at the transmitter buildings of Carnarvon to celebrate its part in global communications development.

Whilst it’s a nice story, it was nowhere near as much of a ‘first’ as was claimed by Marconi (he uses this term in an audio recording at the time of unveiling the statue of Mercury in Australia to mark the event – see links to audio recordings on the next page).

The messages sent from Carnarvon were political and involved important figures of the day. The transmissions would not have been, and were not made on a ‘let’s try and see’ basis. Marconi and his engineers knew that signals from Britain and Germany were getting to Australia, well in advance.



144. *A depiction of Carnarvon, clearly, if only very loosely, based on the view shown in* **15**. *It appears in a commemorative booklet of 1935, to mark the first, 1918 direct message from Wales to Australia with the unveiling of a statue of Mercury, and plaques at Wahroonga, NSW. The buildings are a romanticised re-hash of the station and surrounding buildings, bearing little semblance to their true position. The mast arrangement is wrong, as is the depiction of the masts as lattice, and not tubular type.* ‘An Epoch of Radio Communication’, Amalgamated Wireless (Australasia) Ltd., *State Library of New South Wales, DQ654.164/3, p.8.*

Signals from Marconi’s competitor, Telefunken station in Nauen, Germany, had been received regularly in Australia during WW1. The Amalgamated Wireless (Australasia) company had conducted tests between Australia and Britain for over a year prior to the ‘official first’, according to archive material examined by Mitchell (https://www.qsl.net/vk2dym/radio/Marconi.htm, accessed 19/07/2022) in Australia. Contact with Mitchell could not be established.

AWA engineer, Ernest Fisk, who went on to take part in the 22nd September messages, had also announced in a company shareholders' meeting a month previously that he was able to receive Nauen signals "practically all day", allowing the 'official stunt' to be conducted with confidence and the messages to be received, as Marconi triumphantly declared in 1935, in his self-congratulatory, showman style, "without error". In fact, the messages were repeated several times during that day, to make sure they were received properly (there was no means for Australia to immediately advise of success or failure at the time). The recordings, made onto vinyl, can be heard online. Marconi's partly Irish heritage is clearly evident in his accent (courtesy Essex Record Office).

Side 1: https://soundcloud.com/user-722868764/marconi-side-a

Side 2: https://soundcloud.com/user-722868764/marconi-side-b

Nevertheless, the event was an important public demonstration of long distance wireless, covered widely in the press of the time. The messages were meant to boost support for the war effort from the Australian population at a time when 'led by donkeys' British leadership was resulting in very large casualty numbers amongst soldiers fighting a war half a world away from home.

The messages, sent using 200kW at 21kHz, which vary slightly in minor points of their wording between the very many Australian newspapers, were:

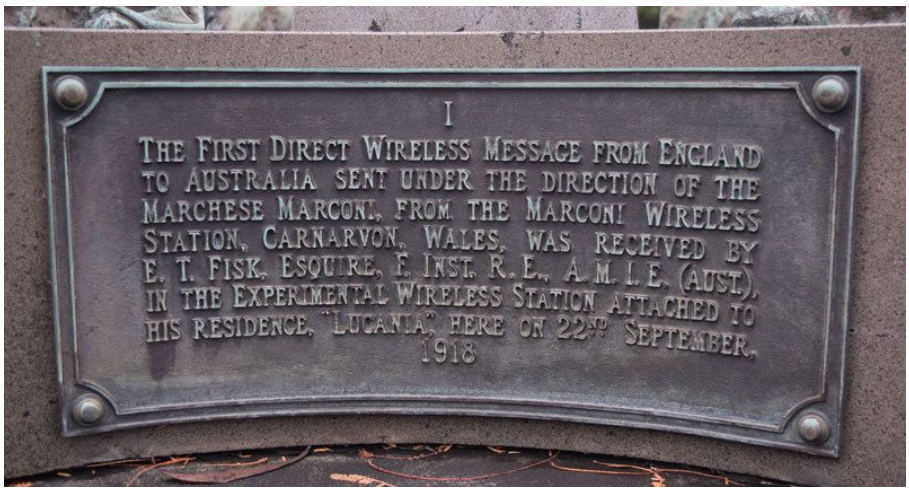
1) 1.15pm Sydney time (03:15 GMT)

"I have just returned from a visit to the battlefields, where the glorious valour and dash of the Australian troops saved Amiens and forced back legions of the enemy, and I am filled with greater admiration than ever for these glorious men, and more convinced than ever that it is the duty of their fellow-citizens to keep these magnificent battalions up to their full strength. W.M. Hughes, Prime Minister."

2) 1.25pm Sydney time (03:25 GMT)

"Royal Australian Navy is magnificently bearing its part in the great struggle, and the spirit of sailors and soldiers alike is beyond praise. The recent hard fighting has been brilliantly successful but it makes reinforcements imperative. Australia has hardly realised the wonderful reputation which our men have won. Every effort is being constantly made here to dispose of Australia's surplus products. Joseph Cook, Minister for Navy."

Sadly, when a copy was to be made for this report of the original transcript of these messages, meant to be hanging on a wall at Amalgamated Wireless Australasia's offices, it was found to have vanished.



145. Plaque erected in 1935 at Wahroonga, NSW, Australia.

Carnarvon made other notable achievements, though they are now entirely forgotten, save for the details held in archived newspapers.

On Tuesday, 10th February, 1920, the first private message sent from Russia began its journey at 01:15 (presumably Moscow local time) – taking just 8 milliseconds to cross the 2695 km (1675 miles) distance – to be received at Towyn. It was sent by *The Daily Herald*'s editor, George Lansbury, a leading socialist and strong supporter of the October Russian Revolution that had taken place just over two years earlier. His message by wireless about Russia's friendliness towards other nations and of a peaceful future was when, Lansbury announced, the "truth blockade" was "broken", his dispatch being "the first instalment of truth" about the situation in Russia (*The Daily Herald*, 11th February, 1920).

On 20th November, 1921, Carnarvon achieved another 'first', direct to Australia, this time using its new valve transmitter. Test telephonic (voice) messages were sent on the Sunday evening of the 20th (Sunday was often the preferred day for such tests, as there was less commercial traffic over the weekends), being received correctly, as Marconi would always highlight (usually misleadingly), "on first transmission" at Sydney and Melbourne (*The Scotsman*, *et alia*, 25/11/1921). The elevated counterpoise ('earth screen') had been installed by this time at Carnarvon as, most likely, had the ~500ft linear extension to the rear of the 1914 antenna.

A curious event took place, noted perhaps not so much for being a 'first' for Carnarvon as a 'last', in "the early hours of" Friday, 16th April, 1926. Capt. [Peter Pendleton] Eckersley, the BBC's Chief Engineer, "pressed a button in Radio House, London, causing a wireless demonstration house [a domestic 'show home'] near New York to be filled with music" transmitted from Carnarvon ('The Magic Button', *The Westminster Gazette*, 16/4/1926, p.7). The reception of the music was by the RCA Long Island station, relayed from there by landline to St. George, Staten Island, where the show home was located. "Aerials built into the walls" were put forward as the model design "to be followed by all enterprising residential developers" – although the landline relay made them redundant for this exercise! Marconi and RCA were intent on building their future broadcast business into the very fabric of all American homes, though Marconi himself never warmed to the concept of general broadcasting.

Just five days later, another piece of Marconi 'first' showmanship was reported excitedly as "London Cheque to U.S. Within Hour" by *The Belfast Telegraph* of Wednesday, April 21, 1926 (p.5). This was to effectively advertise the "commercial possibilities" opening up by way of

‘Radiophotograms’ (wireless static image transmissions) from Carnarvon to America. The $1000 cheque was made out at Radio House in London by General James Guthrie Harbord, then RCA’s president. It was then ‘scanned’ and transmitted, being – within the hour – “presented for payment...in the offices in New York of the Bankers’ Trust Company”. An image of the Prince of Wales at Biarritz was one of the first to be wirelessly sent to New York, for publishing in a magazine, the 5am Late Edition of *The Scotsman* of May 1st, 1926 reported (p.8). The quarter-plate image took 15 minutes to complete. Today, amateur radio operators can do the same thing in just a few seconds.

The Price of Communication.

Use of Marconi’s global network of wireless stations did not come cheap. But then, they were very significant investments – each transatlantic station cost an average of £60,300 at 1913 prices (Draft Specification. *The Marconigraph*, September 1912, pp.213-216), or £6.71 million, using the GDP deflator, at 2021 prices (MeasuringWorth.com). In 1915, after Carnarvon had been in operation for several months, the price of a message sent to the United States, Canada or Newfoundland was, with a *Wireless World* discount of 33.3%, 8d per word (*The Wireless World*, February 1915). In 2021, using the RPI deflator, this amounts to £2.81 per word. A brief, 25-word message would cost a total of £70.25! Each additional word cost 6d, or £2.13. Without the promotional discount, each word would cost around 10½d, £3.75 at 2021 prices.

A message sent from Britain to Honolulu by Marconi’s network was advertised in the same year as 2s 3d per word at ordinary rate, or £9.63 per word at 2021 prices. A ‘night letter’ rate allowed 13 words to be sent for 11s, or £46.89 in total. At the weekend, when business traffic would be largely absent, 25 words could be sent for 14s 6d, £61.81 at 2021 prices. Brevity was a necessary skill! Even so, one newspaper alone – *The New York Times* – received 20,000 words each week in European news *via* Marconi’s stations (Raboy, op.cit. p.347). The presumably special, ‘frequent business’ rate they paid is unknown. But if we take the night letter rate as being the lower end of the scale, then this might have amounted to something like £37,500 worth of traffic each week at 2021 prices.

MARCONI'S
WIRELESS TELEGRAPH
COMPANY, LIMITED

'Phone 10 Lines 8710 City — Marconi House, Strand, London, W.C. Head Office.
'Phone 3 Lines 4800 Avenue — No. 1 Fenchurch Street, London, E.C. City Telegraph Office.
Telegrams: "Expanse, London."

DIRECT SERVICE TO
UNITED STATES, CANADA, NEWFOUNDLAND, &c.
at 8d. per word.
SAVING 33⅓%

In GREAT BRITAIN & IRELAND:

Messages are accepted at Marconi House, Strand, W.C., and No. 1 Fenchurch St., E.C. (both open Day and Night) and at all Postal Telegraph Offices.

In NORTH AMERICA:

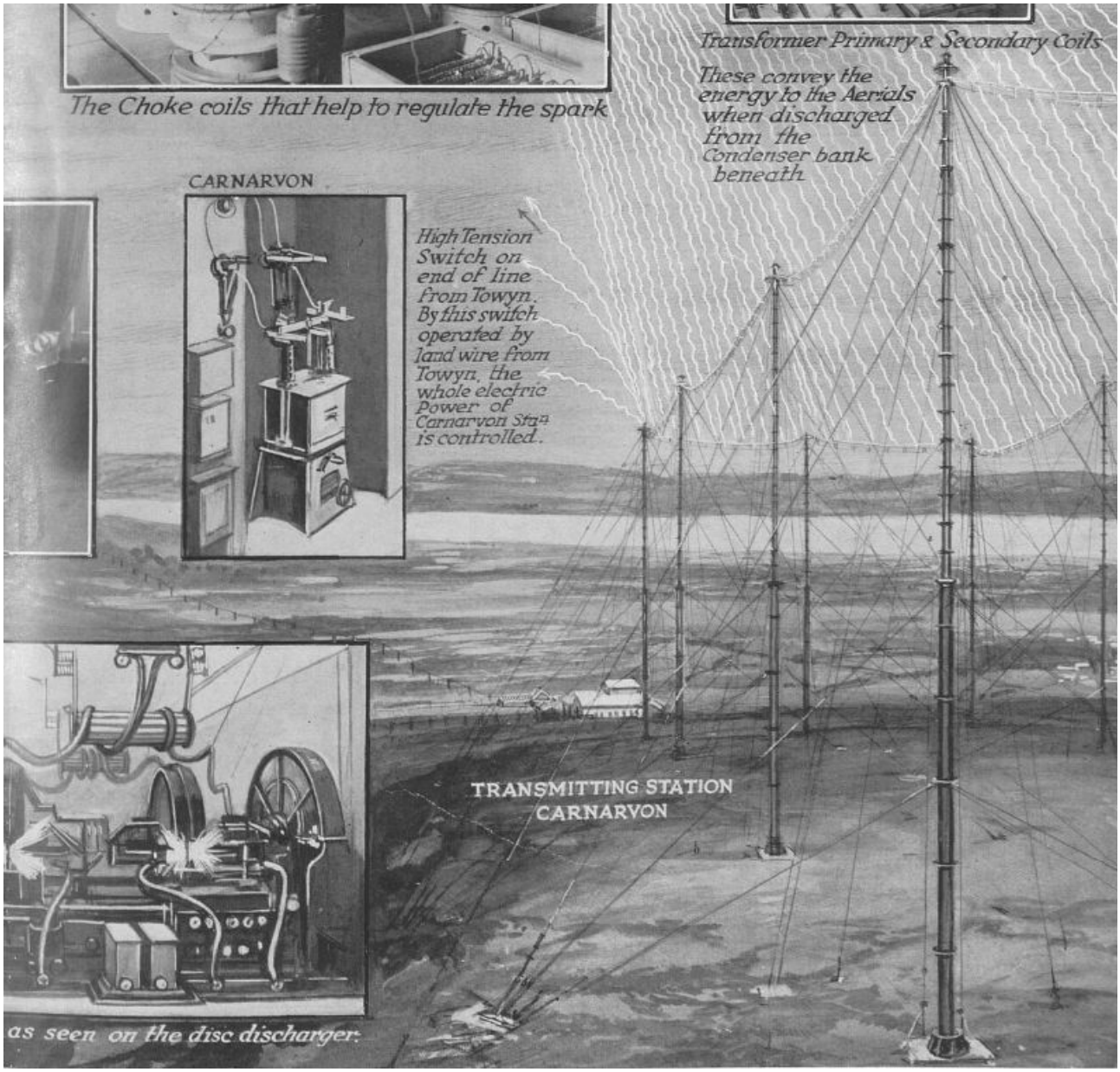
Messages are accepted at Marconi Wireless Telegraph Co. of America, Woolworth Bldg., 233 Broadway, and 42 Broad St., New York, Marconi Wireless Telegraph Co. of Canada, Shaughnessy Bldg., 137 McGill St., Montreal, and all Western Union and Great North Western Telegraph Offices.

Deferred, Night and Week-end Letters accepted at *LOWEST RATES.*

For Tariff giving full rates &c. apply to the Company:
Marconi House, Strand, London, W.C.

146. *Advertisement from The Wireless World, February 1915, p.xxvii.*

An interesting depiction of Carnarvon, alongside Towyn, appeared as one half of a centre-spread graphical feature about the stations in the Saturday, 27th January, 1923 edition of *The Sphere*. The drawing, executed in 1921 by D. Macpherson, is somewhat inaccurate, but is nevertheless valuable.



147. *21kHz 'rays' emerge and go on their way to Belmar, USA, in this graphic of the Carnarvon transmitter site. The number of antenna tube sections is incorrect and the multiple horizontal wire array is not shown. It is, though, a valuable document that shows such things as additional stays, anchors and halyards not visible in known photographs, but physical remains of which do exist. The alignment to the north-west is correct. Drawn in 1921, published in 1923. There were significant changes to the site from around this time. The extensive elevated screen does not appear, suggesting an early 1921 drawing date*

End of an Era.

In 1928, under a Post Office-driven amalgamation of four cable and wireless companies – including Marconi's, the Carnarvon station became part of Cable and Wireless, Ltd.

By this point, VLF stations, though useful at times of geomagnetic disturbances, were rapidly becoming obsolete. Little appears in the press about Carnarvon from around this time, and no significant developments seem to have taken place there from then on. The Cable and Wireless company sought to what they termed 'concentrate' their assets, this involving the closure of several stations, including Carnarvon.

According to an account from the Cable and Wireless archive, now held at Porthcurno Museum, and examined by Paul M. Hawkins (*Point-to-Point: A History of International Telecommunications During the Radio Years*, 1917, New Generation Publishing, pp. 116-121, also pers. com. 13/09/2024), Carnarvon was the first station to come under close scrutiny, during a meeting of the 'Concentration Committee', held by C&W on 18th May, 1938.

The station had, between May 1937 and May 1938, been transmitting for an average of 6 hours per day with a staff of 21. The then Engineer-in-Charge was said, in the 18th May meeting, to be unaware of whether the station was idling or sending traffic, though such a criticism might appear at odds with the average transmitting time statistics presented at the same meeting; it may well have been confected in order to prop-up what was likely a foregone conclusion for Carnarvon. An associated C&W archive folder entitled 'Emergency communications centre' of 1939, lists the salary of Carnarvon's then Engineer-in-Charge, Woods, as £705, or £56,860 per annum in 2023 values by the real wage deflator. The 'STA' - possibly meaning the Senior Transmitter Artificer (G.K. Fagg), earned £435, or £35,080 in 2023 values. Under him, 'TA' staff Spark and Owen both earned £364 or £29,360 pa in 2023 values.

The 30th May meeting stated an intention to try to do without Carnarvon for six weeks, this later translating into an order following a meeting of 13th July for the station to cease transmitting for two months, unless absolutely necessary. The closure was expected to save C&W £26,200 (£3.67 million in 2023 values, using the economic cost deflator). Carnarvon's closure briefly seemed less certain when strong fading on short wave – it was the time of the diminishing peak of solar cycle 17 – caused C&W, in a meeting of 14th October, to wonder whether this was an argument to retain the station. Just three days later, in a meeting of 17th October, this uncertainty had vanished and the decision to close Carnarvon was made.

On 7th of February, 1939, the Air Ministry having dismissed an offer of Carnarvon for its use as unsuitable due to the mountainous terrain a few weeks earlier (reported at a C&W committee of 9th January, 1939) questions were asked in Parliament concerning C&W closures. Hansard, Vol. 343, records the exchange as follows:

> **Major Owen**
> asked the Postmaster-General whether he will state the number and locations of the wireless transmitting and receiving stations Cable and Wireless, Limited, are about to close down; how many stations will remain; and whether he is, on strategic grounds, satisfied that there is an adequate number of wireless stations still remaining at the disposal of this country in times of emergency?

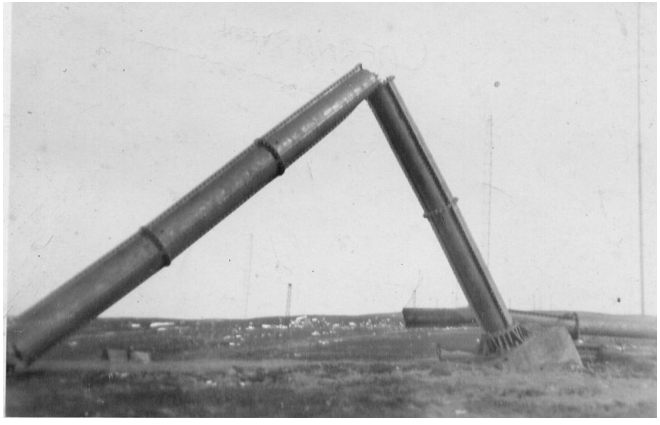
Sir W. Womersley
I am informed by the company that the only wireless station which they propose to close down in the near future is the transmitting station at Carnarvon. This will leave eight stations operated by the company; and as my right hon. Friend the Postmaster-General stated in reply to a question by my hon. Friend the Member for Bodmin (Mr. Rathbone) on 12th December last, the company contemplate the eventual transfer of the installations at three of these stations to other existing stations. The Government is assured that the proposed concentration will not endanger strategic requirements.

Major Owen
asked the Postmaster-General whether he will state the number of men who will be compulsorily retired as a result of the closing down of the wireless station at Carnarvon; what is the average age of these employees; what is the average number of years they have teen employed by Cable and Wireless, Limited, and its predecessor; what compensation, if any, is to be paid to those who are not entitled to pensions; and whether he is satisfied that this is in accordance with the undertaking given in this House at the time of the merger?

Sir W. Womersley
The wireless station at Carvarvon was taken over by Cable and Wireless, Limited from Marconi's Wireless Telegraph Company as a result of the merger in 1928, and no undertaking has been given in this House regarding the staff employed there.I am informed that the number of men who will be compulsorily retired is 16; their average age is 54; and the average number of their years of service is 17. Of the 16 men, 15 are unestablished workmen: they are not entitled to pensions, but they will be given 4½ months' notice and will receive gratuities of half a month's pay for each year of service.

By spring 1939, the station was not only closed – its last transmission was in the preceding November (*Liverpool Daily Post*, 24/5/1939, p.13) - but being demolished and the valuable metals salvaged (British Pathé newsreel 'Felling Masts at Carnarvon', Film ID: 1013.05, issued 1st June, 1939). Salvage was very lucrative; when the 14-mast Marion station in Massachusetts was closed in 1960, some were estimating a value for the materials of up to $10,000, or $71,000 at 2021 prices, using the GDP deflator (Sippican Lands Trust newspaper cutting, unknown source with handwritten pencil indicating V.143, p.216).

Carnarvon's demise saved money for C&W, but was a serious strategic error for wider UK interess which, only a year later, found itself urgently in need of a VLF station away from heavily-populated and thus bomb-vulnerable locations in order to ensure continuity of wartime communication, should Rugby (callsign 'GBR') be destroyed. Carnarvon would have been perfect for this duty but, with nothing of it left, a new station was built at Criggion, Sir Drefaldwyn ('Montgomeryshire').



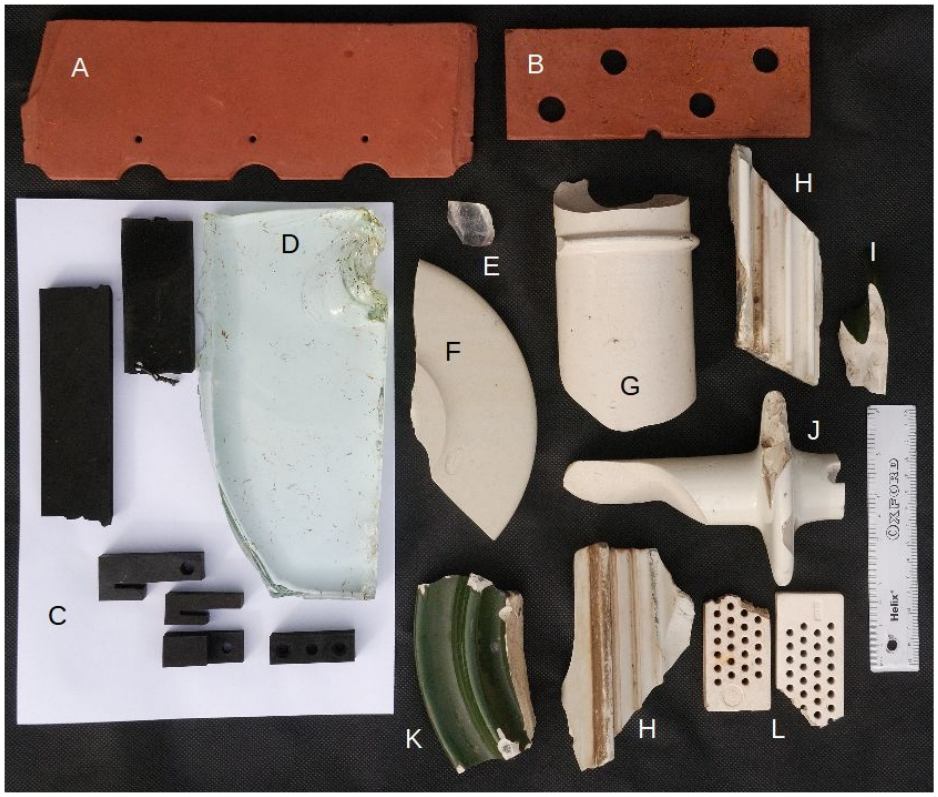
148. *Two felled masts at Carnarvon during station dismantling in 1939. Note the strongly tilted concrete base, shifted as a result of the 400 feet of leverage upon it in boggy ground. Still-erect mast 8 and lattice GMU mast 11 is seen in the background. A few short elevated counterpoise masts are also seen. C&W archive, courtesy Paul M. Hawkins*

Appendix I. Ceramic and associated remains.

The Carnarvon site still retains a large number of ceramic insulators, many of which simply sit on the surface where they were left in 1939. Others lie fully or partially submerged in bog, some occasionally re-emerging from the ground as it slips downhill. There are also early thermoplastic insulators, potentially of gutta percha, to be found. No known effort has previously been made to record and identify them.

Because of the sheer effort put in to dismantle and salvage materials from the site in 1939 many, but not all of the ceramic remains have been dislocated from their original position, sometimes substantially so. It is likely that at least some of the light railway tracks remained in place across the site in 1939, or sections may have been reinstalled, making moving material around and away from the site straightforward. Salvage was a lucrative business for such an extensive site.

Most of the ceramics, being highly specialist components, many perhaps made especially for Marconi stations, were of little value. The complex threading of valuable copper wire through valueless ceramic components meant the latter were smashed where they stood. Some of the ATI house through-wall insulators made it to the summit of Cefn Du and stayed there, in pieces, doubtless thrown away during a sorting process.



C1. *A selection of ceramic fragments commonly found, mostly in relation to the ATI house sites. Rule = 15cm/6".*

A, B: unglazed red ceramic, found within the inductor houses at both ends of the 1923 extension. Probably a spacer for a larger inductor winding.

C: black, probably early thermoplastic fittings, probably once part of an inductor winding.

D: 25mm (slightly under 1”)-thick glass plate of a glass and oil capacitor of the upper ATI house, identified as capacitor K2 in the GLC circuit diagram. The type of of ‘tank’ (oscillating) circuit capacitors they were used within are clearly seen in images of the transmitter buildings (see **C20**)

E: fragment of a glass rod insulator, double ATI house, also found at lower, single ATI house.

F: disc element of a larger insulator, bearing a Royal Doulton, Lambeth maker’s impression. Found at double ATI house, potentially a ‘reel’ type insulator, widely used with radiating and counterpoise wires, multiple examples visible at the counterpoise strainers in image **73**.

G: tubular rod-type insulator, part of the elevated counterpoise attachments at support lattice masts, found at various locations in close relation to lattice masts across the 1923 site.

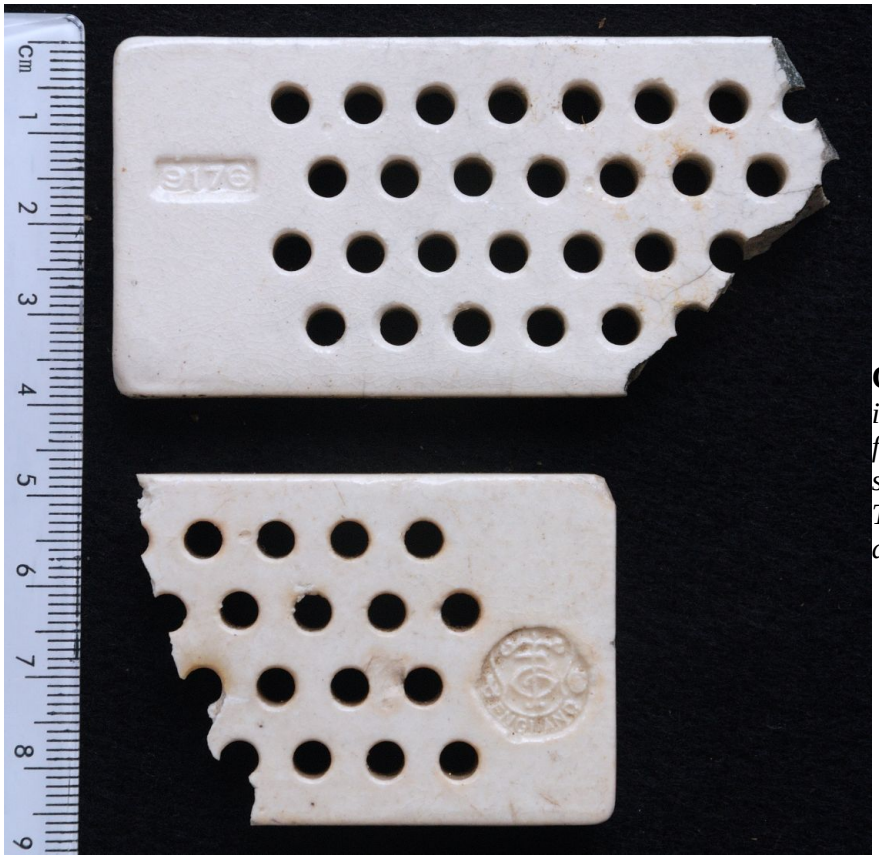
H: insulator with shallow fins, shaped to fit over capacitor lids and clearly seen in several contemporary images of the transmitting sites. This example, amongst many, found at upper inductor house, with examples also at the lower ATI house.

I: Small fragment of a disc insulator, found at upper inductor house. Unknown purpose.

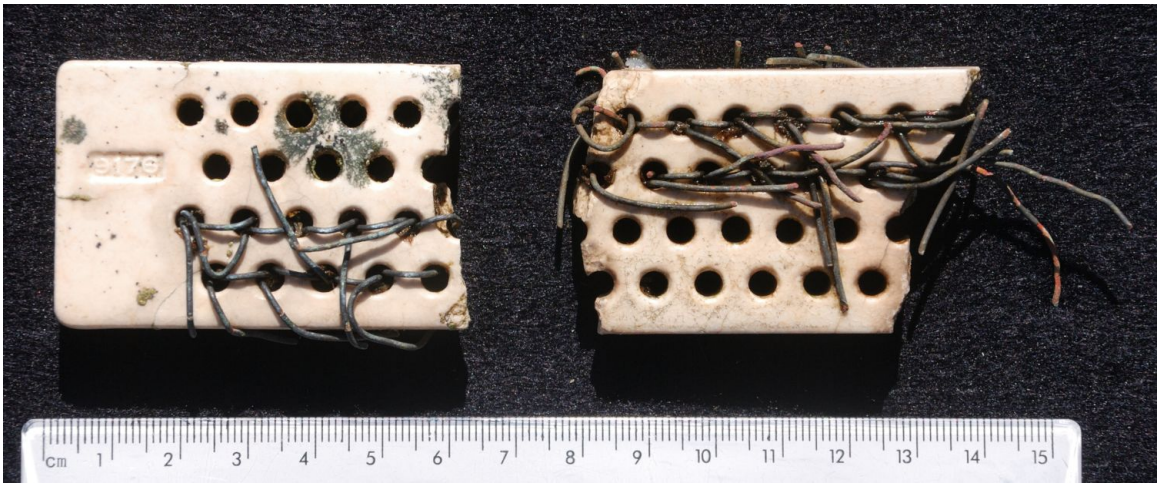
J: Rod and disc insulator, with slot for wire to rest at right. Unknown purpose, but slot at top would guide an overlying wire.

K: Green glazed disc insulator, of which insulator (I) may have been part. Unknown function related to the upper ATI house in which it was discovered.

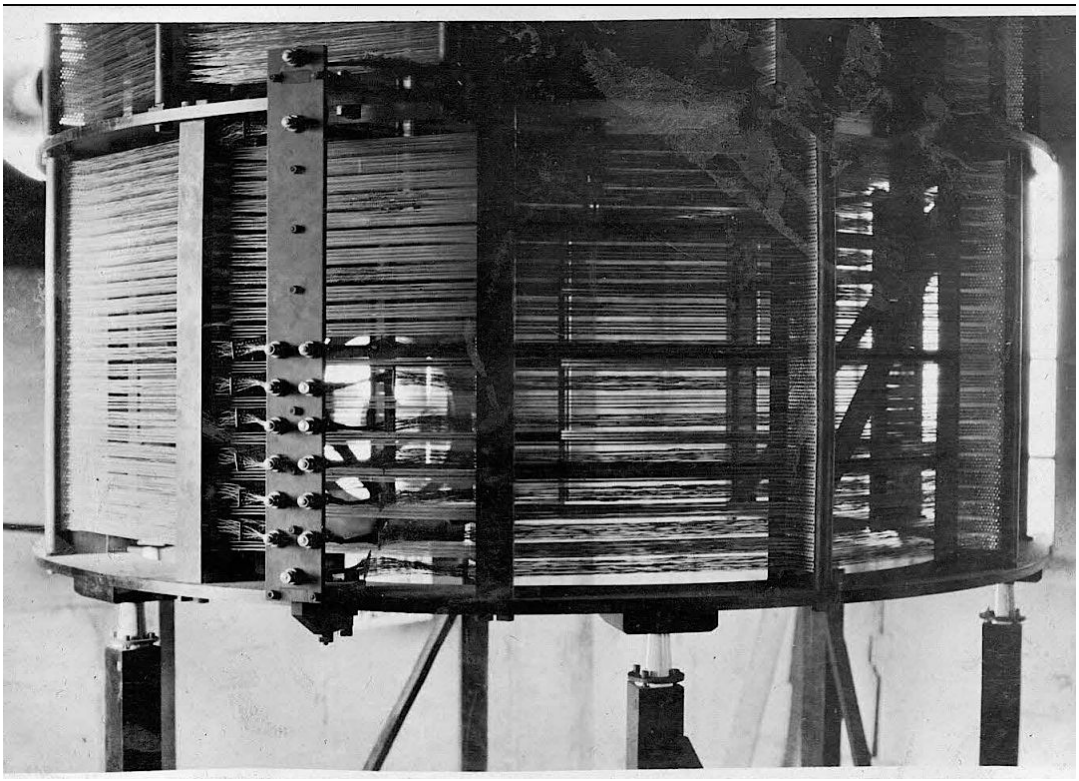
L: White glazed insulators with numerous perforations, bearing Taylor and Tunnicliff maker’s impression and the number 9176. One of a very large number found scattered about the base of both inductor houses, all smashed to speed up copper wire reclamation at demolition in 1939. Though clearly related to the inductors, their exact role was long a mystery until a photograph in MS.Photogr.c.243 revealed clearly that they were spacers for inductor windings. The coil shown at **C5** is probably coil ‘B’, of 24 turns, and having a diameter of approximately 9’ as given in the circuit diagram for GLC.



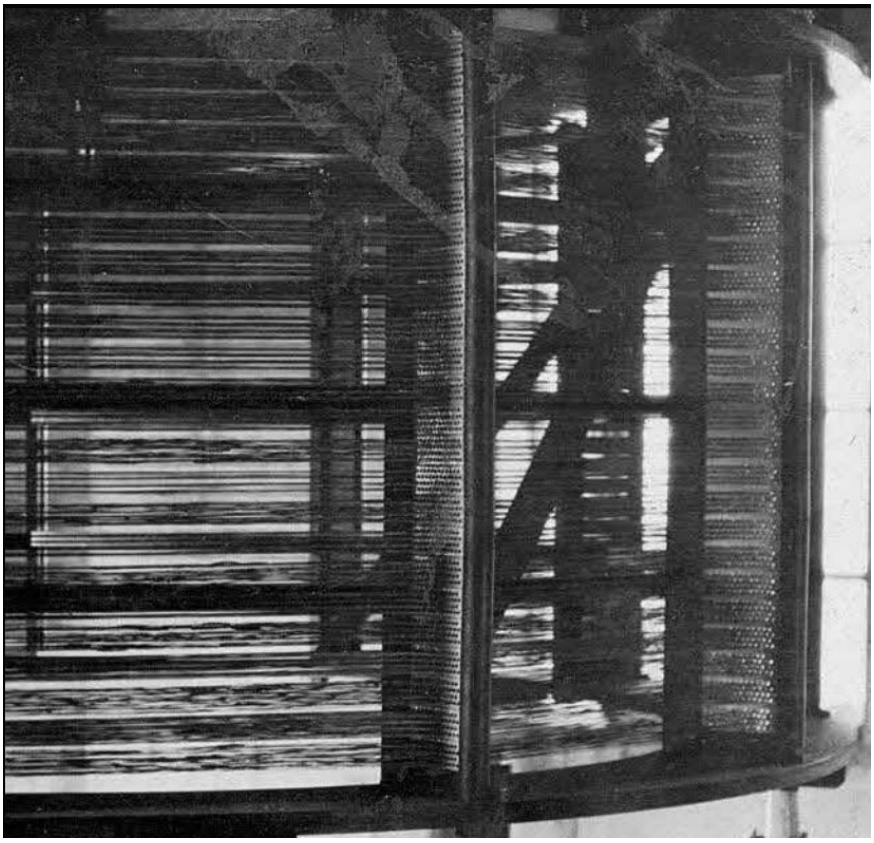
C3. *Detail of insulator 'L' fragments (not the same unit), showing Taylor & Tunnicliff and type marks.*



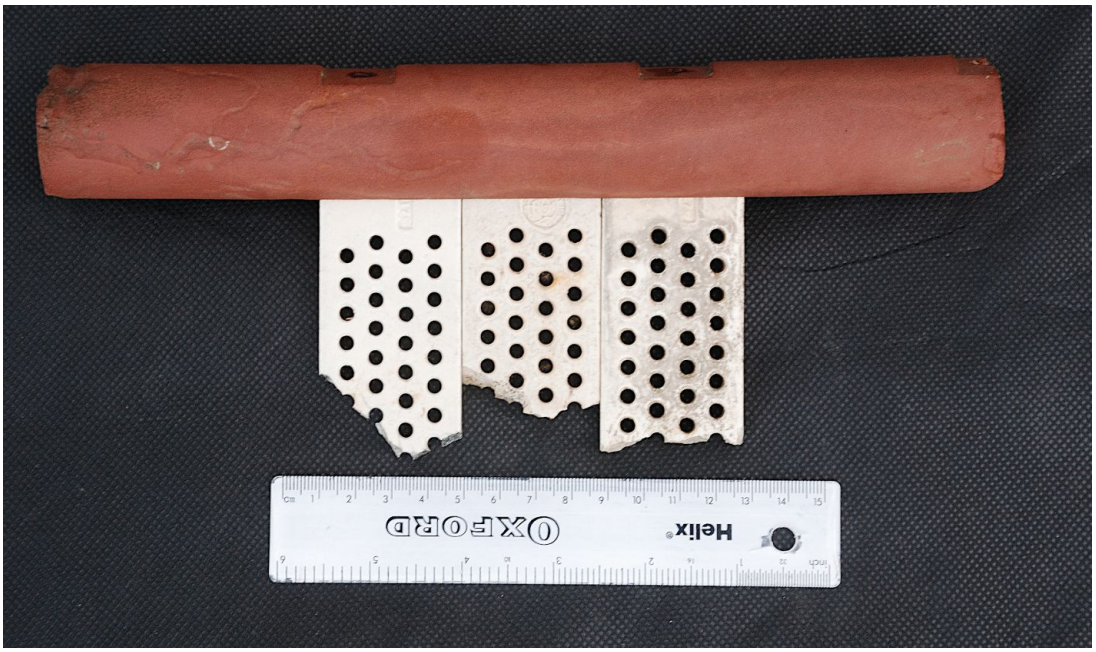
C4. *On one of the last days before fieldwork ended for 2022, these two (separate) fragments of inductor insulator, with wires still attached, were discovered. The wire was passed through a hole, looped around the adjoining ceramic and passed out through the next hole along (lengthwise). A further such example was also found at the lower ATI. Wire ~0.5mm diameter.*



C5. *Inductor, probably inductor 'B' in the GLC circuit diagram, making use of a large number of perforated ceramic spacers. Detail of insulators at* **C6**, *below.*



C6. *Detail of '9176' insulators seen in their role as inductor wire spacers at the upper inductor house.*

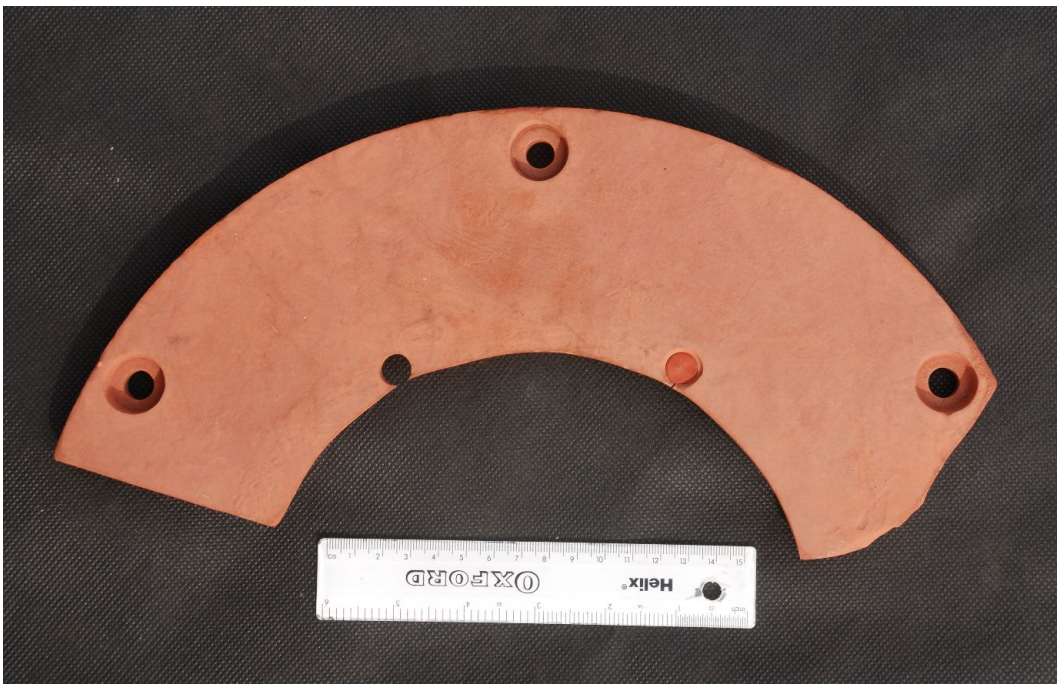


C7. *Slotted, unglazed ceramic rod, in this case, an inductor internal circumference version (as indicated by the flat attachment points at upper) held the spacer insulators in place.*

C8. *Side view of the slotted spacer holder and how the insulators stacked together.*

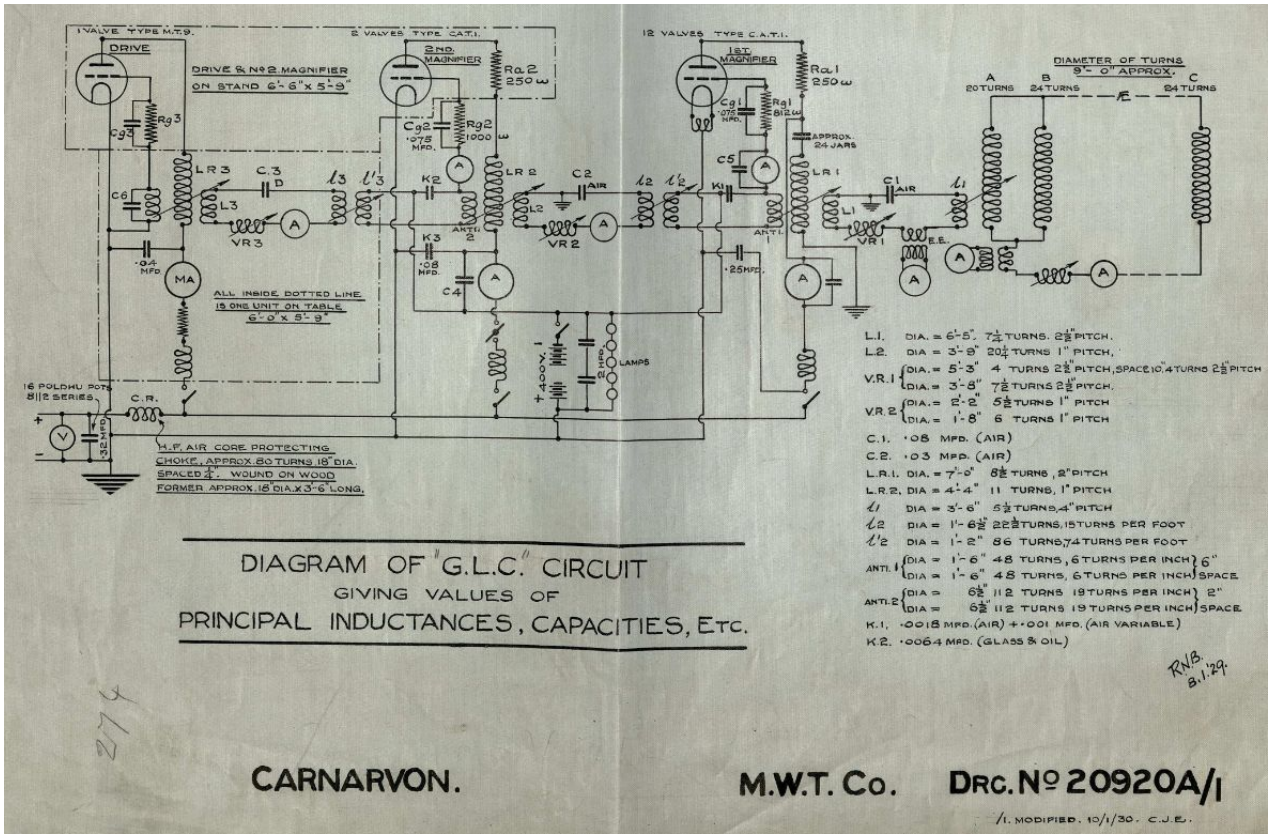
C9. *The slotted mounting insulator shows a distinctive fractal 'lightning' pattern eroded, probably over some time, into its surface, caused by electrical breakdown or 'flashover', which would not be conducive to best transmitting efficiency. Amateur radio operator, Kevin Porter, G6UCY, suggested that a damp environment may have provided conditions more likely to lead to flashover. This is entirely plausible, as the double ATI house is located on wet, boggy ground that was clearly anticipated to be a problem; an internal drainage channel was installed when the concrete base was laid.*

C10. *Doulton impression on insulator F.*



C11, above. *Toroid disc insulator (rear face) of unglazed ceramic, with bolt holes and ceramic, threaded bolts. Found at double inductor house, almost certainly the base or top mounting insulator for a smaller inductor. The GLC circuit detail allows probable identification as inductor* l’2*, indicated as having a diameter of 1’2”, with 86 wire turns.*

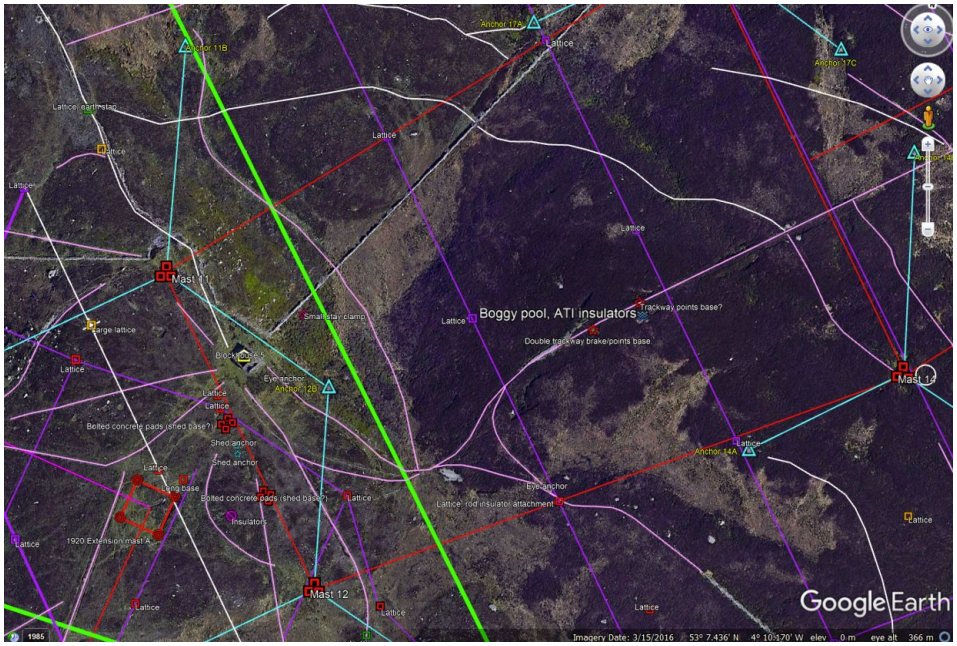
C12, below. U*pper face. Width variable, 85-88mm; inner diameter = 7¼”; outer diameter = 14”; thickness = 18mm. Scale = 15cm/6”. Inner perimeter apparently hand-chamfered.*



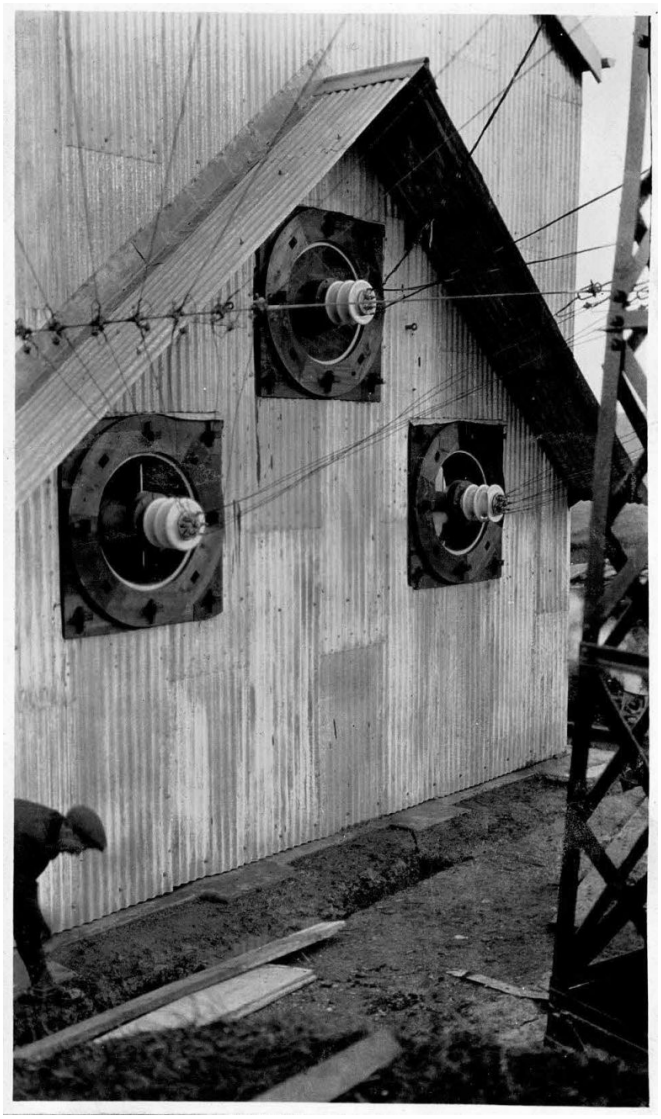
C13. *GLC circuit diagram. Inductor l'2 is seen just to the right of the page fold, upper centre. Image: Bodleian Special Collections, MS.Marconi 198.*

C14, left. *Ceramic fragments from the upper ATI house. Images of the mid-1920s variometer at the transmitter hall indicate both were part of the same unit, a cable retaining ceramic that 'wrapped around' the cable. Right: copper washer from upper ATI house, and slotted-head bolt with washer and copper earthing strap from the lower ATI house.*

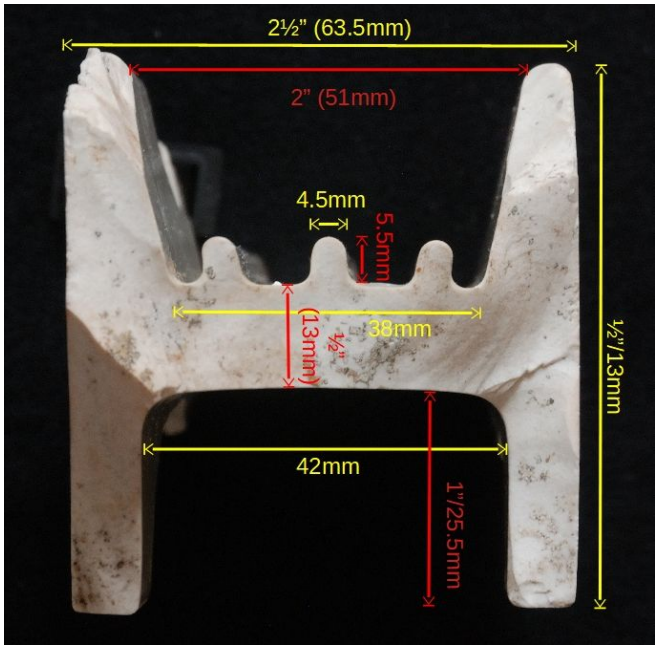
C15. *A very large, cream-white glazed insulator found at a brake/winding base at the top of the incline for construction of the 1923 extension. This was one of the through-wall insulators seen in several photographs of the inductor ('ATI') houses; intact examples are still seen at the transmitter house. Connections were made to a metal plate with a conductor that ran within the insulator and thus passed through building walls. Its position at the top of the incline suggests it was one of the lower inductor house insulators, probably discarded as of no further use after being transported with scrap metal by rail truck to the summit of Cefn Du. Numerous fragments of the same type of insulator, but with a whiter glaze, were found buried in a nearby boggy pool (marked in context, below, at* 53.123069° -4.171382°*).*



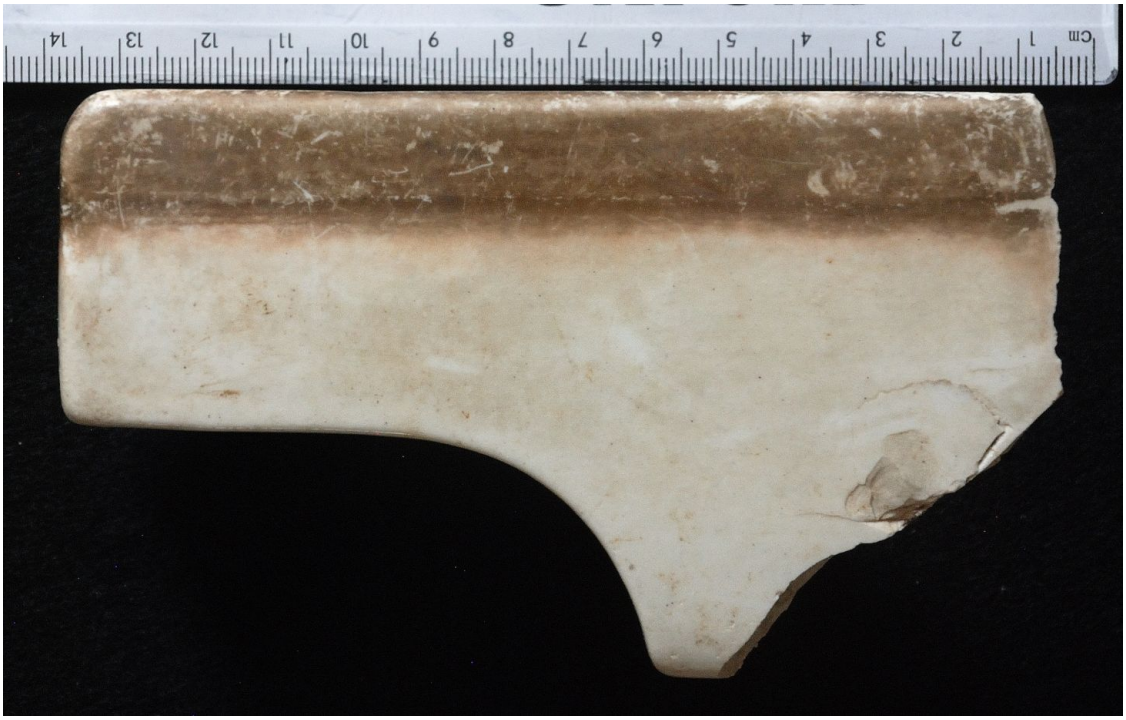
C16. *Location of boggy pool into which the greater part of a large insulator, of the same type as indicated at C15, had been thrown. Its depth in the peat suggests it was deposited upon dismantling.*



C17. *Single inductor house at the lower end of the 1923 extension, showing through-wall insulators of which the fragment at* **C15** *was once part. The insulator at lower right has sustained damage to its edge facing left. Bodleian Special Collections, MS.Photogr.c.243, photograph 746/x.*



C18. *Cross-section of one of very many fragments of a 'bridging' insulator, with three ribs to increase the path for stray current, provide strength and aid heat dissipation. Wide copper strip conductors connected to the bus bars are seen to run along these across the tops of glass-and-oil capacitors in the transmitter house, though this example was found, with many others, at the double inductor house. Archive photos show that these insulators – and the capacitors they bridged – were used over the entirety of the station's 25-year life.*



C19. *Side view of one end of the insulator. No maker's impression has been found on any fragment to date. Scaling from images to fragments allowed the intact length of these insulators to be determined as ~2 feet at the top, ~16" at the bottom.*

C20. *The 'bridging' insulators seen at work, bridging glass-and-oil capacitor tanks of porcelain, in this case, in the transmitter building in 1918. The capacitors were a fundamental part of a resonating, so-called 'tank' circuit, acting in concert with the large inductor coils at background. Strips of copper conductor run inside the insulator channel. Image: Bodleian Special Collections, MS.Photogr.c.243, photograph number P.2072.*

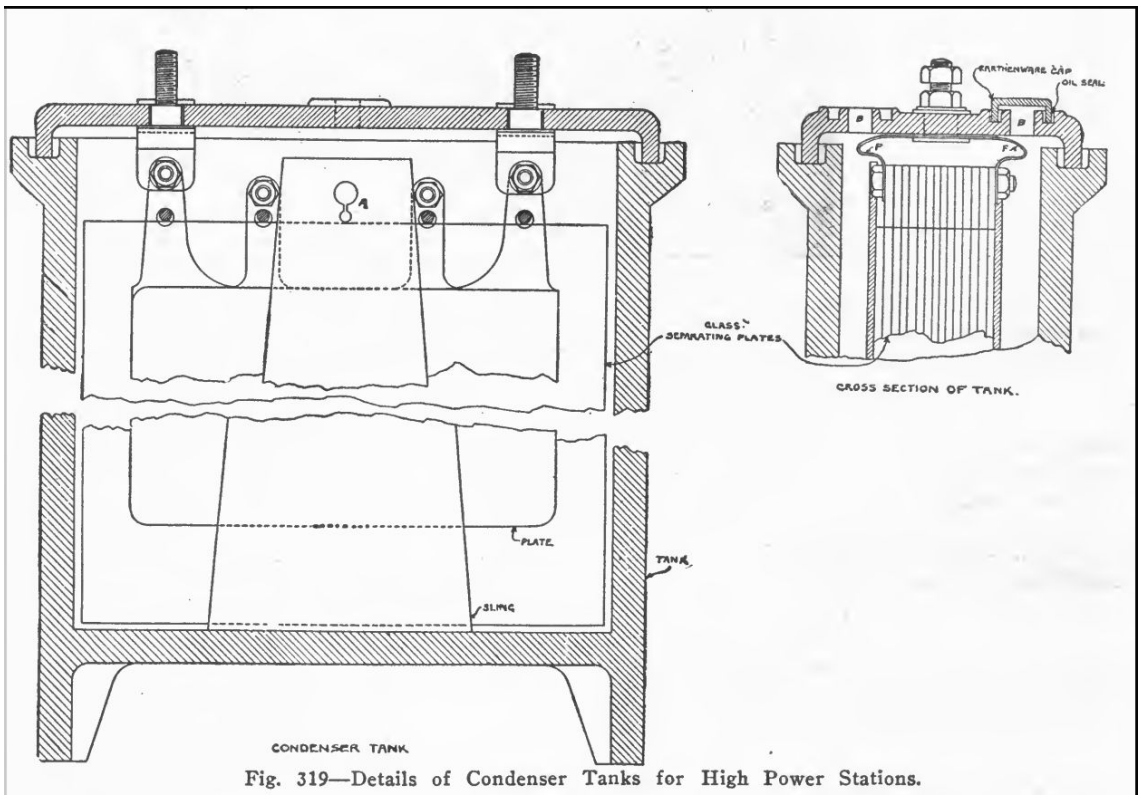


Fig. 319—Details of Condenser Tanks for High Power Stations.

C21. *Detail of glass-and-oil capacitors (Bucher,* op.cit.*, p.304). What appears to be (***C22***, below) one of the connecting tags seen between the threaded lid bolts and a metal capacitor plate, bearing a number '3' was found in the ground at the outside of the entrance to the double ATI porch.*

C22. *Numbered connector tag, probably of an oil-and-glass capacitor from upper ATI house.*

C23. Cylindrical ribbed insulator, bearing Taylor and Tunnicliff impression (at lower left), found at the double inductor house. These had many uses, similar ones seen in use at **C19**.

C24. *Fragments, at least two pieces from the same insulator, where the outer brown glaze has severely deteriorated. These were parts of a nested 'pin' insulator, cemented together, and found close to a counterpoise lattice mast, upon which it is thought most likely was mounted. The larger fragment at far right has a maker's number, P.5656 (see detail, below). The top centre fragment has the same, but partial P.56… mark. A single top piece (not shown) bearing the same P.5656, has a groove of ca. 15mm diameter for receiving a wire, which may add to the belief this was a counterpoise masthead insulator, though the groove may not have been used.*

C25, above: Part of the P.5656, nested 'pin' insulator with a central threaded section containing cementing and a lead (metal) collar.

C26, a and b, below: some of the components still cemented together in a separate discovery. These probably formed part of the earth or feed line system.

C27, right: top element fragment of the same insulator, bearing the P.5656 part number. Little of the original brown glaze remains.

A different class of ceramic was found lightly buried just outside the entrance to the porch of the double inductor house (**C28-C31**). Fragments of what initially appeared to be plastic led to a thick organised cluster of what was in fact mica sheet – part of a small capacitor. Mica-silver capacitors were developed in this period, and the mica may thus have had a thin coating of silver. Such capacitors were noted for their great reliability. Efforts are being made to subject the metal film to elemental analysis.

C28. Part of a mica sheet capacitor, probably a mica-silver type, as there are no interleaved copper sheets as in mica capacitors before this period. Length = 3”, width = 1½”.

C29. *Mica-silver capacitor, as found at the porch entrance of the upper ATI house.*

C30. Sheets of the capacitor, separated to reveal metal, probably silver foil plates, with detail at C31, below.

C31.

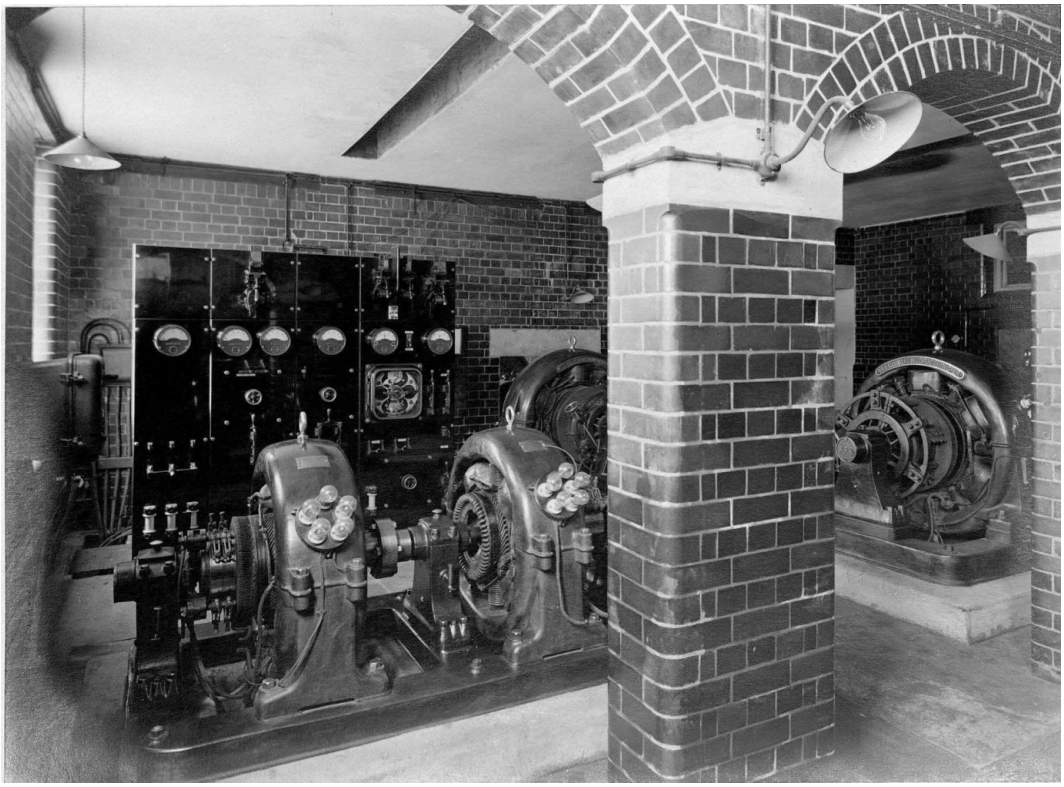
A different form of ceramic – for the building of the transmitter house, can be found littered around the (private) grounds surrounding it. Bricks bearing the maker's mark impression are found to the NW of the building, as are various fragments of white ceramic glass-and-oil tanks. Floor tiles and colourful vitreous-glazed wall tiles, found in most Marconi stations of the time, also litter the area.

C32. *Brick made by Henry Dennis at the Hafod Brickworks, Ruabon (active from ca. 1867). Dennis bricks were claimed to be amongst the best quality and most widely-used bricks in Britain at the time. 'Ruabon' impression mostly obscured at bottom right of central 'frog' indentation.*

C33. *Reverse of transmitter building floor tile, bearing 'Ruabon', 'J.C.E.' and 'N. Wales' impressions, indicating J.C. Edwards (Ruabon) Ltd, active 1903-1956 (Denbighshire Archives, GB 209 DD/DM/27).*

C34. *Purple, vitreous-glazed wall tiles lying to the west of the transmitter building. These were once inside that building. An isolated such brick found nearby (C35, below, in orange glaze) bears impression of Leeds Fireclay Cº Ltd (latter three characters obliterated, but known from example given at* Grace's Guide to British Industrial History, *accessed 17/08/2022). 'England' appears vertically between the deeper frog impressions. Leeds Fireclay Cº was based in Wortley, Leeds, and active from 1889.*

C35. *Vitreous-glazed brick found to the west, immediately outside the transmitter house.*



C36. *Leeds Firebrick Cº bricks in place within the transmitter buildings, providing for a practical, cleanable surface around machinery.*

C37. *Some of the few unpainted bricks within the transmitter building, in use as stables, in 2017 (with kind consent of the owners).*

C38. *At the southern end of the transmitter buildings, a large through-wall white insulator, of the same kind still seen at the eastern, antenna-facing elevation and at both, now demolished ATI buildings, remains in perfect condition. It may have been the connection to a later common earth point to the rear of the building. Alongside, a multi-part green 'pin' insulator, of currently uncertain purpose. A brown multi-part insulator also remains in perfect condition, mounted slightly to the east on the same wall (***C39***, below).*

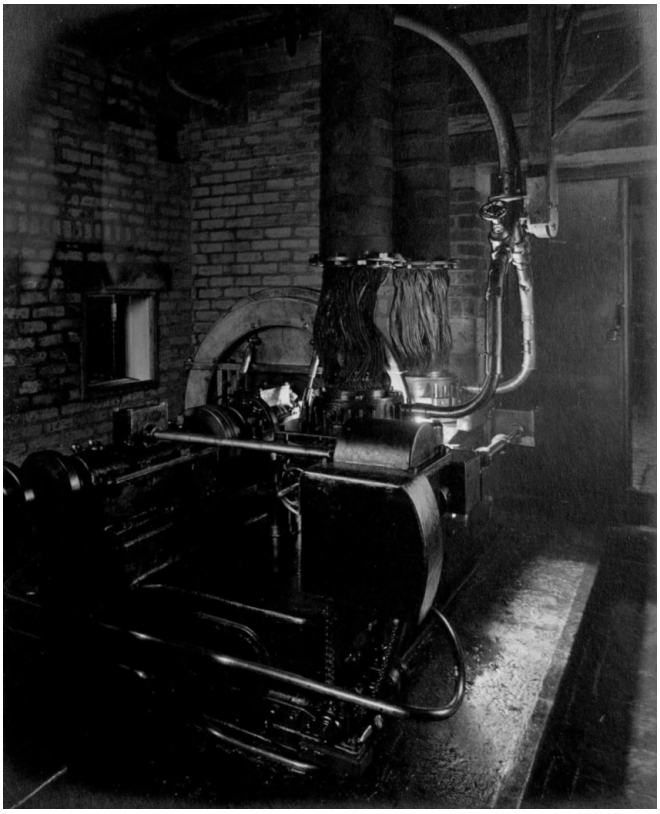
C39.

C40. *The very well-smashed remains, lying where they were dumped at dismantling, partly buried, found close to the eastern end of the upper 1921 extension mast base at* 53.121758°, -4.175346°. *The raised diagonal pattern in the largest fragment at right shows it had another component attached to it, as confirmed by discovery of small fragments with adhesive/cementing attached to them. Distinctive black 'tarline' marks are also evident on the large fragment at left of the trowel. The purpose of this insulator is not known, but it was substantial; the diameter at the upper end of the patterned surface being 14". The curved nature suggests it could have sat on top of one of the ATI house straining towers. Alternatively, it may have been related to the 1921 extension masts, though this is considered unlikely due to the typical use of much smaller, 'reel'-type insulators for that purpose. Further work is needed on the complex fragments. Trowel blade = 6"/150mm.*

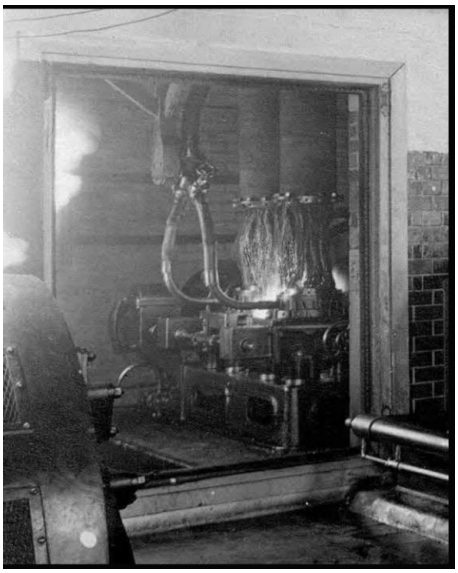
Appendix II.

Carnarvon Station Transmitters.

Carnarvon saw all the latest developments in transmitter technology installed, usually as soon as they were invented. This section does not delve into the detailed technical details as it is mostly, as part of a very visual wider report, to give the reader ‘a feel’ for what it was like to walk into the transmitter buildings, and what the remarkable, brute-force electromechanical means of generating RF energy looked like. At the end of this section, a text reproduced directly from the Marconi archives gives technical detail of each transmitter.

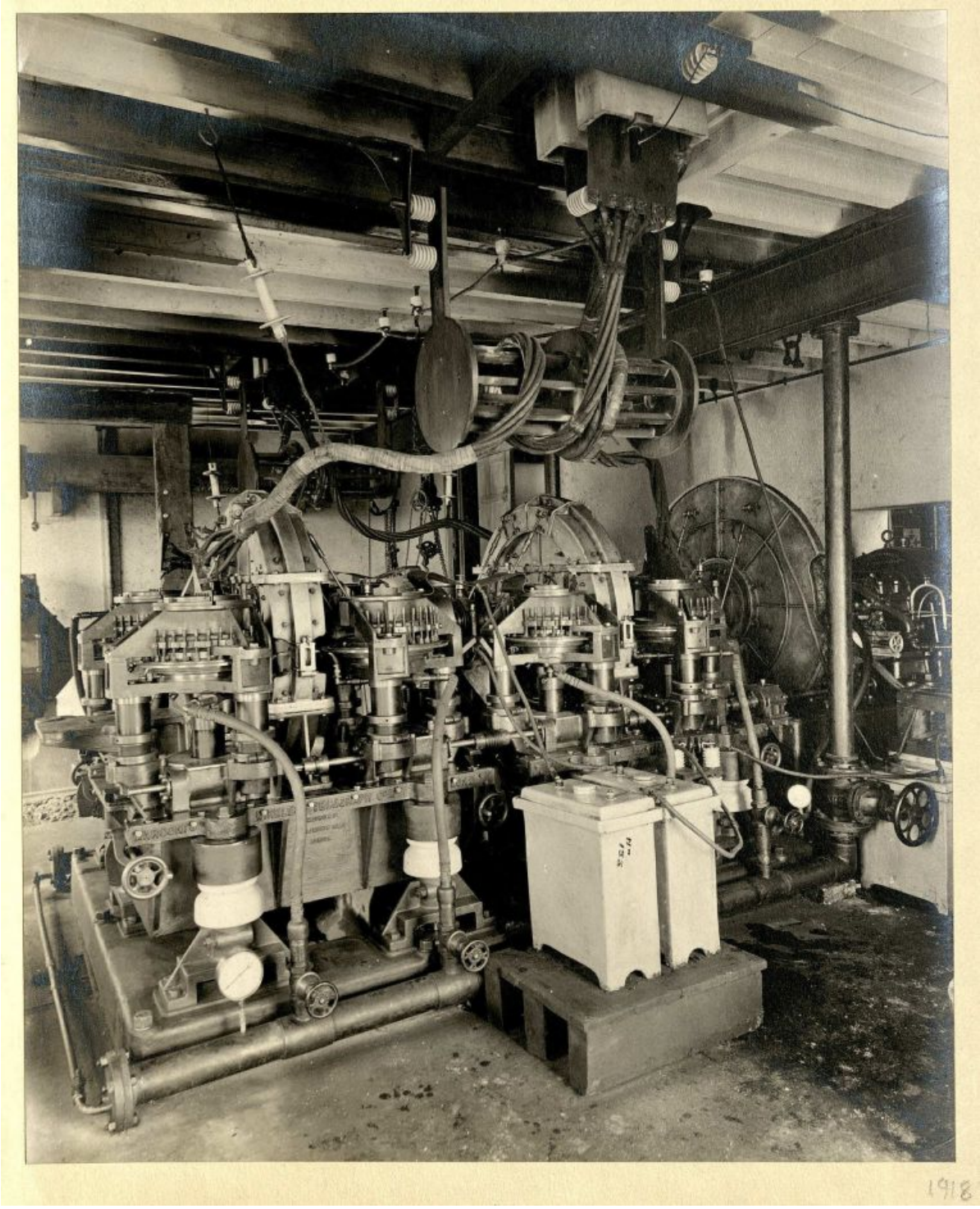


We start with a glorious, long-exposure image (**T1**, left), lit only by its own action, the synchronous spark transmitter. The two bundles of wires seen hanging vertically through tubes running to the floor above are the two ‘poles’ of the underlying oscillating circuit. Between these wires is seen the disc that spun at 1500 rpm. In comparison to the timed disc discharger that superseded it, the synchronous discharger was quite a simple machine. Bodleian Special Collections MS.Photogr.c.243, photo P.2081.

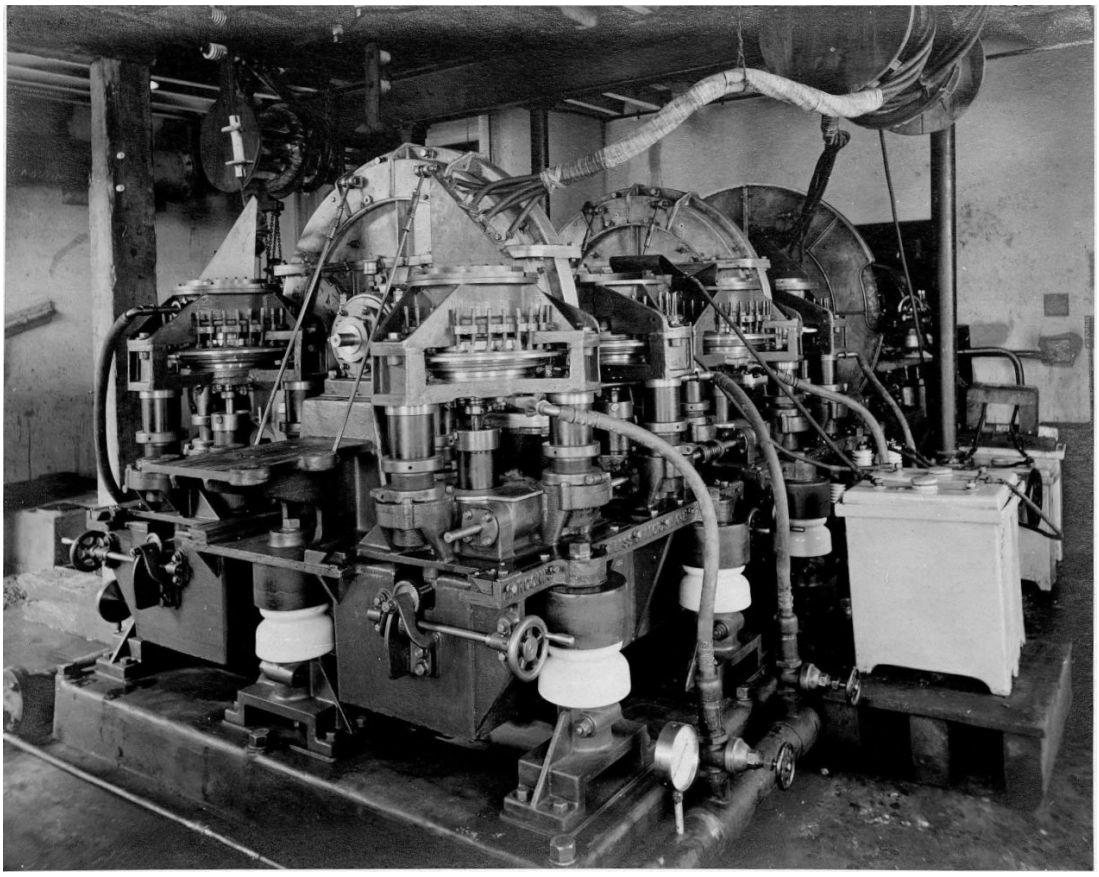


T2. *Detail, right, from a much larger photograph (Bodleian Special Collections MS.Photogr.c.243, photo P.2082), showing the synchronous discharger at work. The exposure of a couple of seconds makes apparent the dramatic spark discharges and allows us to imagine its extremely noisy operation, necessitating a not-very-effective, sound-proof room within which it was ordinarily enclosed.*

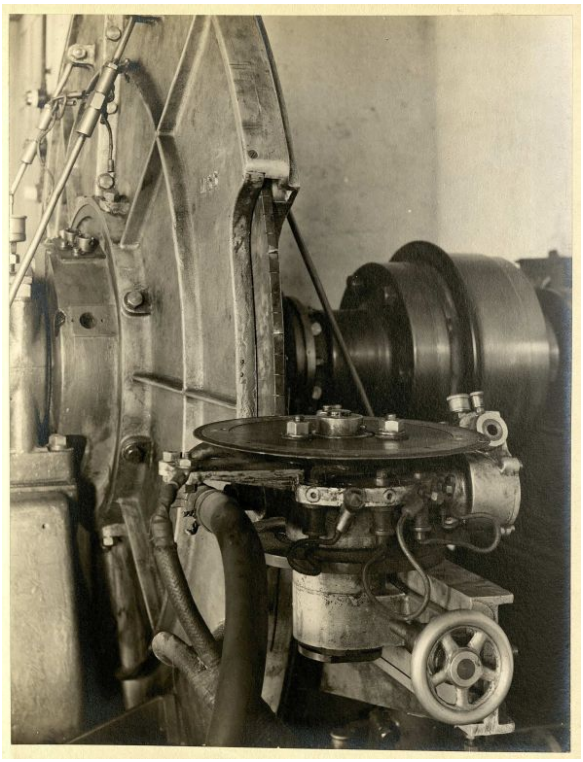
Marconi improved on the simple spark transmitter with the development of the timed spark transmitter. The underlying generating mechanism was the same, but a sequence of discharges were combined to be in phase, thus producing what approximated continuous waves, bringing a much reduced bandwidth use, relative to the extremely broad bandwidth of the earlier spark dischargers.



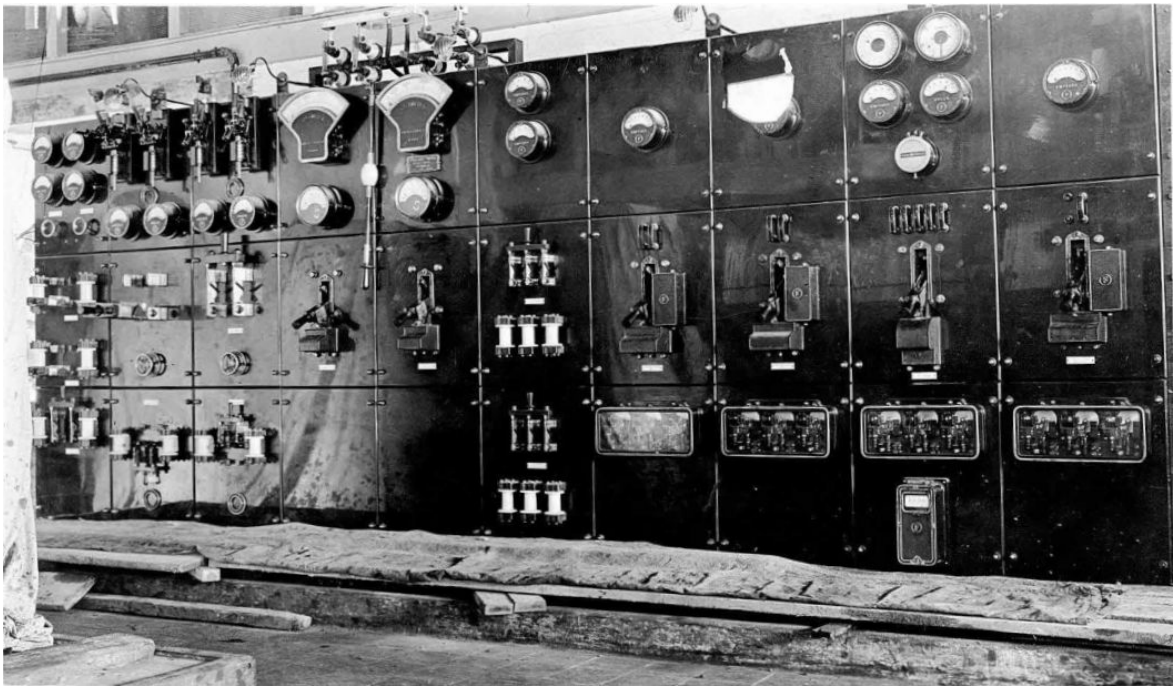
T3. *Carnarvon's 200 kW timed spark transmitter in 1918. This was the very transmitter that sent the first, non-relay, direct wireless messages between Wales and Australia on September 22nd of that year. The two white tanks to the front are porcelain, oil-and-glass capacitors. Bodleian Special Collections MS.Photogr.c.243, photo P.2075.*



T4. *Another view of the timed spark transmitter, 1918. Note the machine's electrical isolation from the base by means of substantial ceramic insulator bushes. Bodleian Special Collections MS.Photogr.c.243, photo P.2076.*

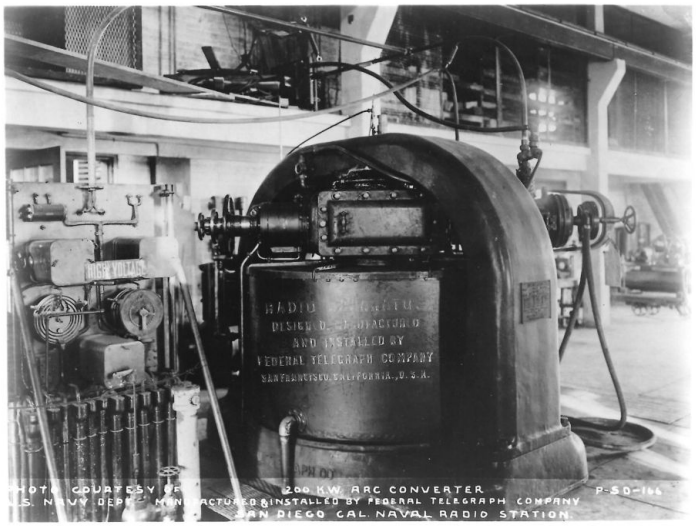


T5. *The timed spark discharger's disc, showing clearly the spiked teeth along its circumference. The disc rotated at 1500 rpm, with a very close fit between it and the encasement. Its driving shaft is seen at centre right. The small disc lying horizontally, at 90 degrees to the main disc, is the timing disc. The rotating timing disc was connected to the electrical supply by means of several wire brushes fixed just beneath it. Bodleian Special Collections MS.Photogr.c.243, photo P.2077.*



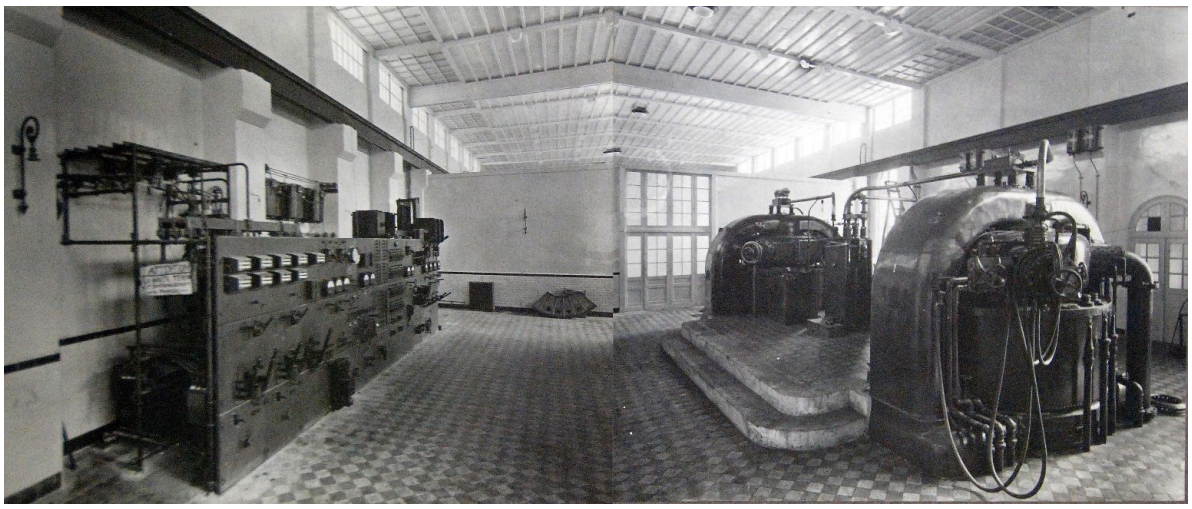
T6. *Carnarvon transmitter control panel as it appeared in 1918. Bodleian Special Collections MS.Photogr.c.243, photo P.2083.*

By 1918, a Poulsen arc transmitter was installed at Carnarvon. Invented in 1903, the transmitter also used sparks, but not rotating discs. Instead, it used an electric arc created by a powerful direct current supply, and converted that into alternating radio frequency current. This was amongst the first transmitter types that could generate continuous waves, so that voice and other sounds could be added by means of amplitude modulation (AM), rather than simple reliance on Morse code, 'on/off' keying. There are no known photographs of the Poulsen arc transmitter at Carnarvon.



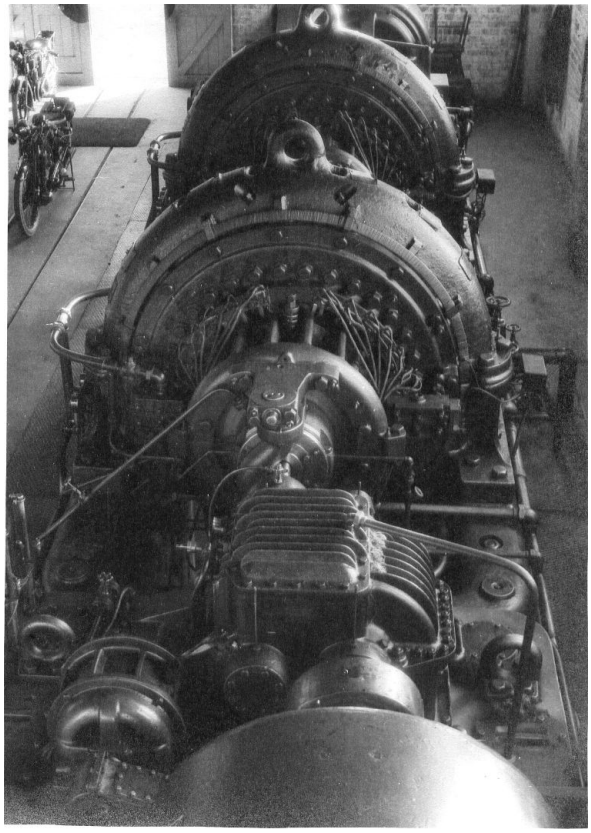
T7. *A single, 200kW Poulsen arc transmitter at Chollas Heights (San Diego) Naval Radio Station, California. The arc there came into service during 1917. Carnarvon received its two Poulsen units, which were similar or identical to that at Chollas, in 1918, but seem to have been largely emergency backup units to the timed disc dischargers, and were found to be unsatisfactory. They were removed from Carnarvon by 1921.*

T8.

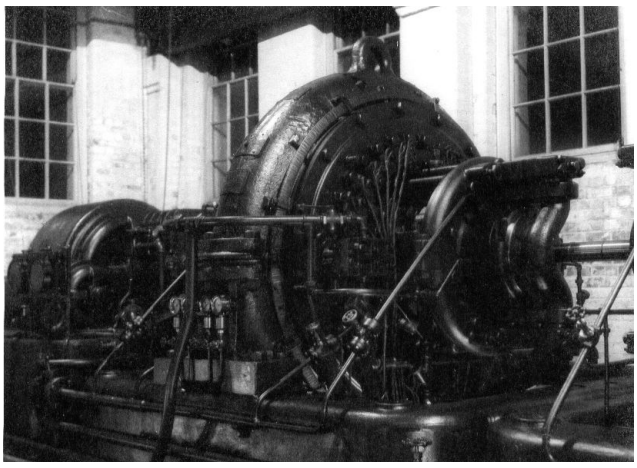


Two Poulsen arc transmitters, of 500kW each, seen in a panoramic, two-photograph image of the transmitter room at Lafayette station, Croix d'Hins, France. The installation at Carnarvon would have looked much the same. Image © Bibliothèque nationale de France, under academic licence.

In 1921, Alexanderson transmitters were introduced at Carnarvon. These spun a large, fluted high-tensile steel disc with a mas of 1,500 kg and diameter of 1.6m, with teeth cut into its edge that, through their infilling with non-magnetic material, provided rapidly-fluctuating changes in magnetic flux. The disc at Carnarvon ran at 2109 rpm (35.15 rotations per second) and, with 610 slots in the disc, yielded a frequency of about 21.5 kHz (Bodleian Special Collections MS.Marconi.198).

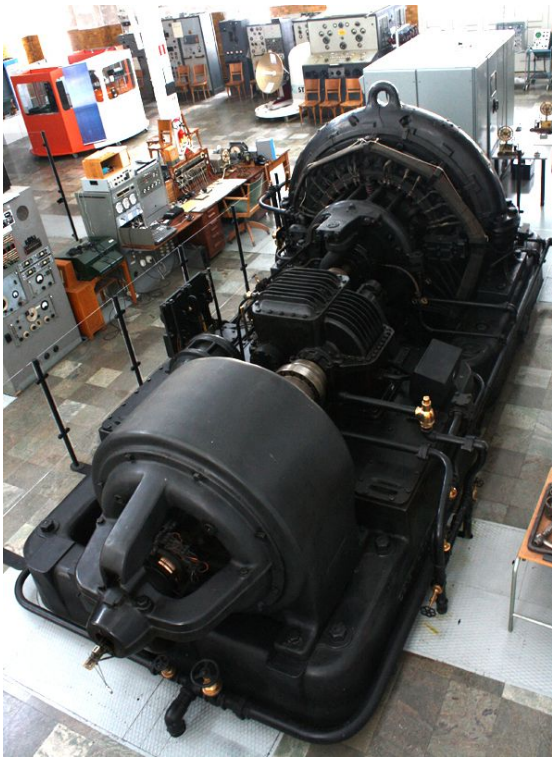


T9 (left). *A recently-discovered photo album of Carnarvon from 1924, taken by then station Engineer-in-Charge, R.N. Barrington, finally lets us see the installed twin-disc Alexanderson alternator. The finned structure in the foreground is the gearbox, running from the motor drive partly seen nearest to the camera. The immense rotational speeds, lubrication and exceptionally-high mechanical tolerances that had to be maintained represented the cutting edge of engineering at the time. All such alternators were made by The General Electric Company, who developed it. By kind permission of Paul M. Hawkins.*



T9a

A considerable volume of material has been written about the Alexanderson alternator, and it would be pointless to reproduce that here. At present, we are fortunate indeed to be able to see, hear and feel such a visceral transmitter – the only fully working example left anywhere on the planet – at Grimeton Radio Station, Varberg, Sweden (callsign, SAQ). Superbly-informative videos of startups of their alternator, to make their (usually) twice-yearly 17.2 kHz transmissions are found online, and the reader is much encouraged to view them and perhaps lend support to the Alexander Association.



T10. *A view of the entire, single disc Alexanderson alternator at SAQ, Sweden. As at Carnarvon, the nearest part is the drive motor, coupled to a finned gearbox at centre, which directly drives the alternator disc at upper right. A feedback system from the disc controls the drive motor to a high, +/- 10Hz tolerance at an output of 17.2kHz. Image: The Alexander Association.*

The technical description, reproduced as issued on 7th December, 1922, below, is from Bodleian Special Collections MS.Marconi.198. It gives a contemporary account of the various transmitters used at Carnarvon.

THE EARLIEST TRANSMITTER.

A description of the various types of transmitters that have been installed at this station, shows very well the progress that has been made in the development of the transmitter for long distance signalling during the last few years.

The original equipment of the station consisted of two 300 kilowatt transmitters of the synchronous Spark type.

This type of transmitter consisted of a copper studded steel disc rotating between two slowly revolving copper electrodes connected to a condenser – inductance circuit. The steel disc was mechanically coupled to the extended shaft of a motor alternator and consequently rotated synchronously with it. The bank of condensers included in the circuit was charged by transformers connected to the alternator and discharged through the gap formed by the copper electrode and rotating studs, the energy in this circuit was transferred to the aerial through an electromagnetic coupling.

The number of studs on the disc corresponded with the number of poles of the alternator and adjustments of the alternator armature were provided whereby the condenser could be charged at the peak of the alternator cycles.

The alternator ran at 1,500 r.p.m. and delivered current at 150 cycles per second, the spark frequency being, therefore, 300 per second.

Signalling was effected by the operation of a switch in the charging circuit of the condenser, an air blast of 2 lbs per square inch, was provided to extinguish the arc which tended to form when the circuit was broken.

The installation of this equipment was completed during the summer of 1914 and preliminary tests were being made with America when war broke out. Up to this time the maximum aerial current obtained with this transmitter was 220 amperes with an efficiency of about 30% from alternator to aerial.

Shortly after this the station passed under the control of the Post Office for war purposes and further developments of the transmitter were prevented.

From the experience gained from the operation of this machine it became evident that for long distance signalling a transmitter producing continuous waves was essential in order to obtain greater selectivity.

TIMED-SPARK DISCHARGER.

At this time no satisfactory continuous wave transmitter was available that would handle the amount of power required for the range over which this station was intended to work. Experiments on a small scale had already been carried out on a machine which produced continuous wave by the proper timing of a series of spark discharges; and as this type of machine appeared to be capable of dealing with the large power required for the station its development was continued at Carnarvon, and resulted in the installation of a 200 K.W. “Timed-Spark” discharger in 1916.

This machine was somewhat similar to the plain spark discharger but with the addition of another disc and circuit for controlling the main discharges. This additional disc timed the successive discharges of the main condenser so that the oscillations produced in the aerial by one main condenser discharge bore the correct phase relation to the oscillations produced by a previous discharge, so as to produce a continuous train of oscillations.

To effect this result, the gaps between the studs and side electrodes of the main disc were increased in length until the voltage across the condenser was insufficient to break them down.

The timing circuit was then so arranged as to produce an ionising spark across the main gaps which would allow the main discharge to take place, and adjustments were provided to control the instant at which this ionising took place.

By this means a series of discharges at perfectly regular intervals took place and by running the disc at a constant and definite speed, the oscillations produced by the successive discharges could be brought into phase with one another and so produce a continuous wave.

The oscillations produced by this type of transmitter although continuous were not of constant amplitude; as, owing to the damping of the aerial circuit, the oscillations produced therein decreased in amplitude in the interval between successive discharges of the primary circuit.

In order therefore to maintain the amplitude as constant as practicable a high rate of primary discharge was necessary; and for this reason two separate primary circuits were employed in the final arrangement of the transmitter.

Shortly after this machine was put into service the wavelength at which the station operated was changed from 11,000 metres to 14,000 metres; and for the latter wavelength a primary discharge frequency of 1,580 per second was used giving an impulse to the aerial every 15 ½ oscillations.

The condensers of the primary circuits were charged by a 5,000 volt direct current generator of 300 K.W. capacity, the charging current being 50 amperes. With this input to the machine an aerial current of 280 amperes was obtained on a circuit of 2.1 ohms resistance giving an efficiency of 66% from d.c. machine to aerial.

Signalling was affected [sic] by means of a key in the condenser charging circuit of the timing disc; and as this circuit took only 0.3 ampere at 5,000 volts a high rate of speed could easily be obtained.

On full power perfect signalling from this machine has been recorded at 195 w.p.m. but owing to the comparatively slow rate at which the current in the aerial rises, this speed of signalling is not practicable for working over the maximum range, as the signals do not reach their full strength in the dots of the Morse Code.

As soon as this machine was put into service, the manufacture of a duplicate set was put in hand but owing to the delay in obtaining the necessary material, delivery could not be expected for a considerable time.

POULSEN ARC TRANSMITTER.

In the meantime therefore a Poulsen Arc Transmitter was installed as a reserve for the "Timed-Spark" transmitter in cases of emergency during the war period. This, however, was not found to be very satisfactory as it was incapable of delivering more than 170 amperes to the aerial, and could not be worked for long period without giving trouble.

At the conclusion of the war, the commercial service with the United States of America was started up, using the Timed Spark discharger that had been installed in 1916. The second set was delivered in 1919 and both machines gave excellent service.

Incidentally, it may be mentioned that is was with this transmitter that the first messages were sent direct from this country to Australia in 1918.

In 1920 improvements in receiving circuits were being rapidly made with a view to obtaining still greater selectivity and freedom from interference, and in order to take advantage of these improvements it became evident that it was necessary to employ a type of transmitter which produced continuous wave of constant amplitude and freedom from harmonics.

The Valve transmitter, although giving excellent results, on low power stations, was not at this time sufficiently developed for high power use, the only other type of transmitter which would meet the requirements at all satisfactorily being the high frequency alternator.

ALEXANDERSON ALTERNATOR.

In order, therefore, to take full and immediate advantage of this improvement in reception, it was decided to install high-frequency alternators of the Alexanderson type without delay.

In order that there should be no interruption of the commercial service an additional building was put up in which to install these machines and work was commenced in July 1920.

Two 200 K.W. machines were delivered in September of that year and were installed and under test in April of 1921.

These machines are of the inductor alternator type, with solid steel rotors having 610 radial slots cut in each side of the rim, the slots being filled in with non-magnetic material in order to reduce the windage losses.

The armatures are built of laminated iron strip .0015 inch in thickness enamelled on each side to avoid eddy currents, the armature slots being cut in the faces between which the rotor rotates, and the gap between rotor and stator being .035 inch.

The rotor is maintained in a fixed position by the use of equalising levers, having an adjustable controlling bar between them which exerts a thrust on each end of the shaft; and by the same device wear of the thrust bearing on each side of the rotor is automatically taken up.

The bearings and thrust bearings are lubricated by pressure feed at 15 lbs per square inch from a pump, chain driven from the gear shaft, during periods of starting and stopping oil being supplied by a separate motor driven pump.

Water cooling is provided for the bearings and also for the armature, copper tubes for this purpose being let into faces of the latter next to the field frame.
The alternator is driven by a 420 B.H.P. 2,200 volts 2 phase motor through a double helical gear of ratio 2.973 to 1, flexible couplings used between motor and gear and between gear and alternator.

For a wavelength of 14,000 metres the alternator runs at 2109 r.p.m., and as wavelength is inversely proportional to speed the latter must be held within very close limits.

To obtain the close regulation which is necessary, one of the alternator armature coils is used for speed regulation. This coil supplies current to a capacity-inductance circuit having a resonance frequency slightly higher than the required alternator frequency.

Working at a point on the steep part of the resonance curve of this circuit, the current rises or falls rapidly due to a change in the alternator speed. A small proportion of this current is drawn from the circuit through a magnetic coupling, and by means of a rectifier is made to operate a relay which controls variable impedances in the motor circuit.

These variable impedances in the phases of the motor circuit consist of coils wound on iron yoke, the iron being more or less magnetized by d.c. current supplied by a generator, the fields of which is controlled by the above mentioned relay.

With maximum field on the generator, the d.c. current supplied to the impedances, or "saturation coils" as they are termed, is sufficient to saturate the iron and the inductances of the a.c winding is a minimum; and with no field on the d.c. generator the inductance is a maximum. In order to compensate for the signalling load relays working synchronously with the signalling key are also provided to cut out resistance in the rotor circuit of the motor, and also to reduce the impedance in the stator, the amount of "compensation" being adjustable to suit the load on the alternator.

Signalling is effected by means of a variable impedance, known as the "Magnetic Amplifier" shunted across part of the secondary winding of the transformer connected between alternator and aerial circuit.

The variation of impedance of the amplifier is obtained by varying the magnetization of the iron on which the shunt coils are wound, a separate winding supplied with d.c. current at 240 volts being used for this purpose.

The minimum impedance is given by a current f 20 amperes in the d.c. winding and maximum impedance by no current in the d.c. winding. The signalling key consequently breaks and makes a d.c. current of 20 amperes at 240 volts for "marking" and "spacing" respectively.

VALVE PANEL.

These machines have given very satisfactory service for the past twelve months. With the introduction of very low damp "filter circuits" for receiving and the consequent greater necessity for constancy of

wavelength, it was considered desirable to employ the Valve transmitter which, since the installation of the Alternator, has been developed at the Station for high power use.

This type of transmitter very well satisfies the requirements of modern receiving apparatus. It emits a pure wave of constant wavelength, permits of a high rate of signalling and combines constancy of wavelength with high efficiency and low running costs.
Moreover, unlike these transmitters which employ for the produc[t]ions of oscillations complicated machinery which must be installed in duplicate to ensure continuous service, duplication of the oscillation generator in a Valve transmitter is unnecessary. The reason for this is that the generator panel consists of a large number of comparatively small units in parallel, the failure, for any reason, of one unit not materially affecting the output of the generator as a whole, permits replacement of the units at a favourable opportunity.

Fifty-six valves of the type known as M.T.2 are provided on the main panel which consists of an iron framework with clips for holding the valves, and on which are mounted also the condensers and resistances for the grids of each valve.

The filaments of the valves are connected two in series, the current taken by each pair being 10 amperes at 40 volts, the centre point of the series connection being earthed.
The potential changes on the grids of the main valves necessary to produce oscillations are controlled by a separate circuit, which is maintained in oscillation at the desired frequency, energy from this circuit being transferred to the grid circuit of the main panel through an electromagnetic coupling.

The anodes of the main valves are connected to one end of a winding which couples to a circuit containing an air condenser inductance coil, variometer and coupling coil, the latter transferring energy from the closed circuit to the aerial.

The other end of the anode coil is connected to a source of high potential and the action of the transmitter as a whole is as follows :-

Direct current at 10,000 volts is fed to the anode circuits of the controlling valves. The circuit which is in resonance with the main circuit frequency, is set into oscillation by the usual “reaction” between anodes and grids, and by means of the coupling potentials from this circuit are transferred to the grids of the main valves. The anode circuit of the main valves being fed with direct current at 10,000 volts, these variations of potentials on the grids produce oscillations in the main circuit, the energy from which is transferred to the aerial through the coupling provided.

Signalling is at present effected by short circuiting a resistance between the direct current machines and the anode circuit of the main panel, and air blast being provided to extinguish the arc which is formed on opening the key.

This method of signalling permits of a speed of 85 words per minute but arrangements are being made for the keying to be done in the controlling circuit, which alteration will enable the speed of signalling to be easily doubled.

This transmitter is now being used to handle traffic with New York, the signalling keys being operated by a Post Office Type B relay.

By means of change-over switches, this relay may be operated either by a hand key or Wheatstone transmitter at this Station for testing purposes, or by the Wheatstone transmitter at the operating Station at Towyn, one of two metallic loops connecting the two stations being used for this purpose. The second loop is used for a telephone circuit for convenience in handling service messages between Carnarvon and other offices.

The transmitters, which all operated on what we today call renewable energy from the Cwm Dyli hydroelectric power station, required large volumes of water for cooling. For this, a substantial reservoir of 50,000 gallon capacity was built into the ground, 980 feet to the ESE of the transmitter building, and 135 feet uphill of it. It was also the supply for fire fighting (which proved critical in 1921). It is covered by a significant volume of earth today, but is presumably of concrete construction. This is an interesting feature worthy of future study.

T11. Panoramic image, looking south, of the 50,000 gallon reservoir.

T12, right: aerial drone image of reservoirs, the largest of which is outlined in green grass growth around most of its perimeter. The smaller reservoir is at top centre right. The internal construction is likely to be multiple brick pillars supporting a concrete roof. There is a likelihood of that roof's collapse at some point.

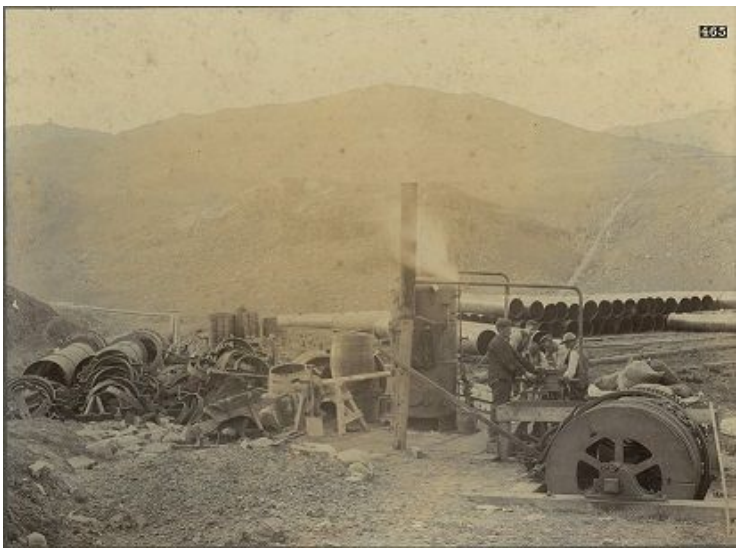
A very much smaller reservoir to the south of the main reservoir is of uncertain purpose (**T13, T14**, below, from west (to bottom of images)), and has a valve mechanism at 1.3m below water level. It is fed by a slightly diverted stream running to the south. It may be connected to the larger reservoir.

Cwm Dyli Hydro Plant

An important element of Carnarvon's existence, not given sufficient attention in the first edition, was the hydro power plant at Cwm Dyli. It was built by the North Wales Power and Traction Company, completed by mid-1906 (*Baner ac Ameserau Cymru*, 13/6/1906, p.5) for an abortive electrical train route for the Beddgelert and Porthmadog line (*Baner ac Amserau Cymru*, 21/3/1906, p.7) and for supplying local villages and slate quarries. The access road became for a time a matter of dispute between the power station's owners and the local council (*Baner ac Amserau Cymru*, 13/6/1906, p.5). The turbine generators lie within a striking building, loosely in the form of a traditional Welsh chapel. It is often claimed to be the earliest grid-connected hydro plant in the world.

T15. *Cwm Dyli hydro plant, built 1906. Image of summer 2023.*

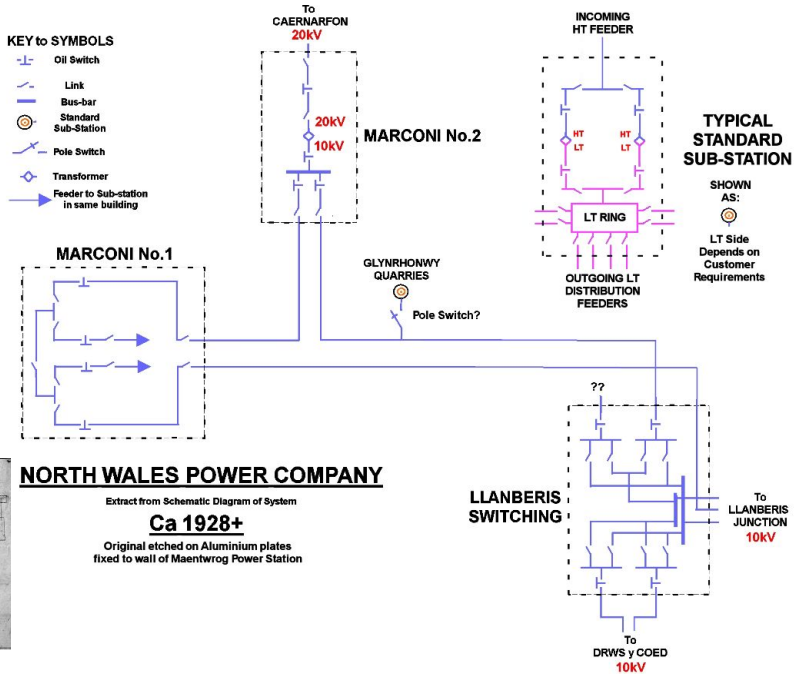
The electrical transmission lines for Carnarvon were 10kV and routed down Bwlch Llanberis (pass) to a switch house above Llanberis village.

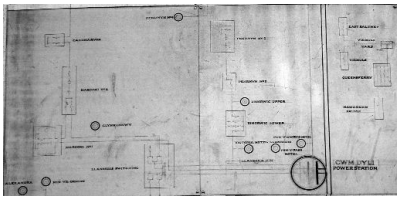


T16. *Portable steam-powered haulage winders during construction of the Cwm Dyli water supply system from the lakes above the station. The same haulage system was used for construction of the Carnarvon site.*

An enquiry with industrial archaeologist, Graham Isherwood brought to light a *ca*. 1928, poor copy plan, inscribed on aluminium plates at Dolgarrog hydro plant, of the early North Wales grid, which includes the Marconi station with two transformers and the adjoining Glynrhonwy quarry.

T17. *Schematic, courtesy of G. Isherwood, based on plates (inset, below, taken 2023) depicting the north Wales, hydro-based AC network still displayed within the turbine hall at Maentwrog hydro station.*



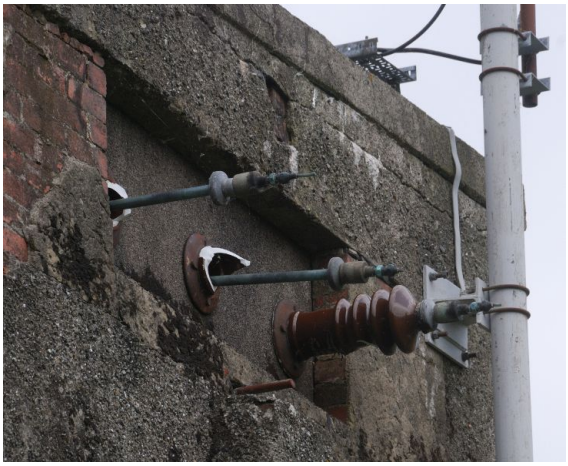


The Llanberis switching house still exists though, again, it had not been recorded by the historic environment professionals, despite being a very obvious feature in the landscape. It has more recently been repurposed as an emergency services 'Tetra' communications relay station – thankfully without too much harm to the structure. Due to the present study, the switch house has now formally been assigned a National Primary Records Number (NPRN) of 800088 (SH5746358733).

T18. *The striking 1906 Llanberis electrical switching house, part of the Cwm Dyli hydro-powered AC distribution grid for the area, including the Marconi station, where at least two transformers were fed.*

T19. *Internal view of the Llanberis switch house. Insulators for the feeds were fitted to slate panels installed in wall openings. The pattern of standoff insulators on the three walls is very evident.*

T20. *One insulator survives in relatively intact state on the south east elevation. This was for the onward transmission, up Maesgwm and towards the Nantlle quarries. The feed for Marconi station was on the opposite, northwestern elevation.*



APPENDIX III.

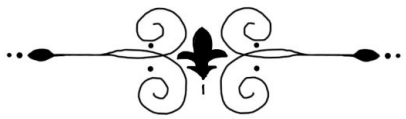
The Marconi Agreement with the Government

In September 1912, *The Wireless World* published the draft specifications for the Imperial Chain. This was the result of a painfully slow, bureaucratic process that began in March 1910, when Marconi first approached the Colonial Office about a wireless chain to connect "the Crown Colonies and the Dominions beyond the seas".

On August 7th, 1912, the government finally, after an immense amount of dilly-dallying, settled upon and made agreement with Marconi's Wireless Telegraph Company as the provider for what was very much the communication system of control of Empire.

The draft agreement should not be read as a definitive account of what was actually installed when it came to constructing the sites; the clue is in the word 'draft', and should be noted well. For example, the sectional masts to support the radiating wires were 400' (probably 412') in practice, not 300' as given in the draft text. Improvements in wireless technology over time, which were remarkably rapid, meant that the specifications in the draft for what would be used to achieve the aim of continuous communication quickly became obsolete, and changes were continuous during this and other Marconi stations' lifetimes.

The draft is reproduced in the form it was presented in *The Wireless World*, with the only modification of clearer paragraph spacing to make reading easier.



"BELOW we present an abstract from the draft specification, submitted by the Marconi Company, descriptive of the wireless telegraphic installation under the contract for the Imperial wireless stations :

The installation to be designed for efficient transmission at full power, and to be capable of transmitting to the distant station, with which it has to communicate, at all times of the day and night.

The wave-lengths of all stations in connection with the Imperial scheme shall be as great as possible within the limits of 17,000 ft. and 50,000 ft. (consistent with keeping the capacity inductance and size of the aerials within reasonable limits) in order to ensure reliability of reception at all times of the day and night, but the wave-lengths transmitted from any one station will be in all cases at least 25 per cent. different from those transmitted from other stations within its normal range, and with which it has to communicate.

In the case of the English [sic] station, the wave-length chosen for communication with Egypt will be 30,650 ft. approximately. In all cases throughout the Imperial scheme there will be a difference of 5 per cent. between the wave-lengths emitted from any one station in order that

each corresponding receiving station with which this station has to communicate may be able to tune out the waves emitted by the said station for the other station or stations with which it is also communicating. In the case of the English station the above-mentioned wavelength of 30,650 ft. has been chosen in order that there will be no mutual interference with other high-power stations existing or in contemplation within the range of the English station. Each station shall be capable of communicating with its respective corresponding stations at all times, and in order to effect this the station will be designed with high aerials and considerable reserve of power over what is required theoretically to bridge the respective distances ; and, furthermore, where a station is required to communicate in more than one direction, separate transmitting circuits to be provided, and in such cases the characteristics of each transmitting circuit will be identical, except in so far as it is necessary to vary the inductance of the H.F. circuit according to the wave-lengths to be transmitted.

The note of each station will be different from those of any other station within its range, but the notes of each transmitting circuit in any one station shall be identical. Facilities shall be provided, however, for slightly altering the note of any one of the transmitting circuits in case it may be found at any time desirable to do this. In order to standardise the apparatus so that the staff of one station shall be equally competent to look after the plant of another station, the power plant and heights of the aerials and types of machines and apparatus shall be, as far as practicable, the same in each case, and the types of prime mover and generator shall be, where possible, identical in each case.

Aerials.—The size of the aerials in each case to depend upon the length of wave emitted. The capacity of the aerial shall be such that under working conditions the voltage shall not rise sufficiently to produce a bright brush discharge. The length of each wire used in the aerial shall be electrically identical, and the wires shall be insulated throughout their length. The transmitting aerial to be of the multi-wire directional type—i.e., with the centre line through the horizontal portion of the transmitting aerial coinciding with the line of direction of the station with which it is required to communicate, the free or elevated end of the aerial pointing directly away from the communicating station. The English aerial to consist of a number of parallel wires. each wire being composed of seven strands of No. 19 S.W.G. silicon bronze wire. Each wire will be over 3,000 ft. long, and insulated throughout its entire length. The aerial will be supported by 10 sectional tubular steel masts, each 300 ft. high. The aerial will be suspended from the various triatics by means of porcelain rod and reel insulators. The aerial will pass freely through the porcelain reel which is attached to the bottom of the porcelain rod insulator. The triatics will be made of 1½ in. circumference extra flexible steel wire rope, having a breaking strain of 7½ tons.

Masts.—The masts for supporting the aerial shall be of the 2 ft. 6 in. sectional steel tubular type, and shall be 300 ft. high in each case. The aerials to be supported on triatics stretched between pairs of masts. Each mast to be capable of withstanding a permanent horizontal strain of not less than 2 tons at the head of the mast, in addition to windage calculated at the rate of 30 lb. per effective square foot. The masts will be provided with a suitable number of steel wire guys insulated from the masts and attached to anchor blocks set in

the ground. Earth System.—This system to consist of a series of galvanised iron plates buried in a suitable position relatively to the station house. This arrangement to be supplemented by a number of horizontal wires running to the boundaries of the site. The set of plates outside the building to be connected by suitable leads and carried into the building and thence to the various circuits.

Power Plant.—The power plant to be in duplicate, and to include two steam boilers (each capable of evaporating sufficient water for the whole requirements of any one transmitting circuit). In the case of stations required to send in two directions three boilers arc to be provided ; and in the case of stations such as the one in East Africa, required to transmit in three directions at the same time, the station is to be provided with four boilers. It is mentioned that the prime mover in each case is to be a steam turbine, direct coupled to an alternating-current generator which in turn will be coupled direct to a Marconi revolving disc discharger. Excitation for the alternators will be provided by two 110-volt turbo-generators, which will also supply the lighting of the building, fans etc. The total power at the terminal stations to be 1,300 H.P., and at the intermediate stations to vary from 1,900 H.P. to 2,500 H.P., according to the locality, range and number of directions in which transmission is required.

Each boiler to be of the water-tube type, to have a grate area of not less than 3,000sq. ft., to be designed for a working pressure of 200 lb.per sq. in., and to be provided with super-heaters capable of raising the temperature of the steam by 200° F. of superheat. The condensing plant to be in duplicate and of the surface type.

Transformers.—Each station to be provided with five transformers for each transmitting circuit.

Inductances.—The inductances for regulating the condenser charging circuit to be of the Marconi latest improved air -core type. Other air -core inductances to be provided, placed in the leads from the secondary inductances to the condensers for the purpose of preventing surges of voltage being set up in the transformers.

Shunt Protectors.—Shunt protectors of the graphite or lamp type to be provided as shunts across the windings of the fields and armatures of all machines in the station in order to prevent oscillations being set up in the various windings of these machines.

Condenser Rank.—The station to be provided with a separate condenser bank for each transmitting circuit, consisting in the case of the English station of 540 cells. Each cell to be of special and improved design, consisting essentially of the same number and type of plates as in the original Poldhu jar type of condenser, but these plates to be mounted in a special form of ironstone containing vessel. The containers to be self-insulating, thus dispensing with the necessity for the provision of insulated stands. Further, the lids of these containers to be provided with a heavy oil seal to prevent the internal insulation being affected by moisture reaching the inside of the condensers. Each cell to be provided with high tension terminals connected to the plate lugs,

and formed to take the external 'bus bars in a convenient fashion. The connections between the individual cells will be formed of copper strip. The whole design of the transmitting circuit to be such as to obviate the necessity of any changing in the grouping of the condenser cells, the capacity in this circuit being kept at a fixed value, and any required variation in wave -lengths being obtained by regulation of the inductance of the jigger primary winding or the connections thereto. The main 'bus bars from the condenser to lead to the jigger and discharger and to be so arranged as to reduce the inductance of these leads to as low a figure as is required. The leads from the 'bus bar connections to be so arranged that the spare alternator and disc can be quickly connected thereto, and the other disc disconnected.

Disc Discharger.—The station to be provided with one disc discharger for each transmitting circuit and one spare. Each discharger to be of the Clifden type, modified to suit the requirements of this service, with special side electrodes, and provided with the necessary number of studs. The disc will be provided with an insulated coupling between the disc and alternator shaft, and means will also be provided for driving the disc from an independent motor.

Transmitting Jigger.—One transmitting jigger to be provided on each circuit for use on the full power of the installation, the jigger to be provided with a multi-stranded primary conductor arranged in conformity with the latest type of jigger as used at our Clifden station ; the secondary of this jigger to consist of a special solenoid winding of similar cable to the primary winding, but of smaller size. The primary and secondary windings to he entirely separate. And the secondary to move laterally with regard to the primary to enable the coupling of the two circuits to he varied.

Aerial Tuning Inductances.—The stations to be provided with aerial tuning inductances of an approved design.

Signalling Gear.—The station to be provided with not less than three relay operating high-tension signalling switches on each transmitting circuit, which will be inserted on the lead from the low-frequency inductance to the condenser bank, thus affording control over the charging current to the high-frequency primary circuit. Above the high-tension signalling switches will be installed isolating switches to enable any of the switches to be connected or disconnected at will. The electro-magnets of the high-tension signalling switches will he operated by means of a relay current, the relay being situated in the transmitting station. The relay will, however, be operated by means of a Morse hand key. situated in the operating station several miles away. The relay will also be capable of being operated by means of a Wheatstone or other automatic transmitter, also situated in the operating house, and means will be provided to enable the operation to be carried out by hand or automatic at will. The transmitting station will, however, be provided with a Morse hand key to enable signalling to he carried out from the transmitting station should it at any time be necessary to do so.

As regards the receiving and operating stations, they arc not to be less than xi) miles distant from the transmitting stations. The receiving aerials are to consist of one or more silicon -

bronze stranded conductors supported by sectional steel masts 300 ft. high. The receiving aerial is to be erected parallel with the centre line of the transmitting aerial, and in the case of the English station the receiving aerial wires will be approximately 8,000 ft. long. This aerial is to be supported by sectional steel masts each 300 ft. in height, the masts to be of the sectional tube pattern, efficiently guyed and connected to anchor blocks by flexible steel-wire stays suitably insulated from the masts. The earth system is to consist of a number of galvanised iron plates buried in a suitable position relative to the receiving house, and at a radius of 200 ft., and connected to the receiving circuit by a number of radial galvanised iron wires, the earth system being further supplemented by a number of similar wires attached to the outer plates and running below the horizontal portion of the directional receiving aerial. The operating room is to be furnished with Morse hand keys and Wheatstone or other similar type of automatic transmitters with suitable switch arrangements, so that operating can he effected either by automatic transmitter or by hand key. The receiving station will be further provided with a small outbuilding containing a 5-H.P. petrol engine coupled to a direct-current dynamo, for supplying lighting to the building and current to the operating line. A storage battery of adequate capacity also to be installed, so that current can he taken from the battery or generator at will."

Appendix IV.

Examination of Blockhouse 5.

This section was issued, prior to publication of the main text, as part of a critique of earlier interpretation of several features at the Marconi Carnarvon site by official archaeologists.

The all-brick element initially had firing holes spanning the length of all four elevations. As their purpose was to allow firing at an approaching enemy, the firing holes had to have a clear line of sight, and could not be obstructed.

We know that the brick element was erected within weeks of the outbreak of WW1 (e.g. ‘Troops at Marconi Works’, *The North Wales Chronicle and Advertiser for the Principality*, 30th October 1914 – the word ‘Principality’ curiously omitted from the title when cited by GAT, and which could be taken as amounting to modern revisionism).

The stone element, even in its derelict state, still has the top of its eastern elevation higher than the direct sight line of the few firing holes still open. This would not be conducive to hitting the enemy, and is the first piece of good, but not conclusive evidence against the stone element being a 'cell' of an earlier stone building.

H1. *View from the NNE of the eastern elevation (right) of the brick blockhouse and the southern (centre) and eastern (left) elevations of the stone element. The camera is at firing hole aperture height, and projecting their viewing lines forward to the part-ruined eastern stone elevation shows the view out onto the wider site, for all of them, to be mostly or entirely obstructed by it.*

H2. *The eastern elevation of the brick element, viewed here from the south, has two gutter downpipe brackets remaining mortared between bricks, with no indication – such as hacked-out or replacement mortar, that these were installed at any time other than that of its construction. If the stone element was earlier than the brick, then the downpipes would have discharged internally into the stone part – an unlikely scenario, especially when the only practical roof form for the stone element at this point would be a single-pitch, 'lean-to' sloping flat roof where such downpipes would have been entirely unnecessary. No guttering is seen for either the brick or stone elements in photographs of 1923, which strongly suggests the stone element was a post-1914 addition. This is the second, compelling set of evidence against the idea of stone building predating the brick element.*

The stone foundations are put forward as evidence for the earlier stone building. Examination of other blockhouses, however, reveals that they *all* have stone foundations and have varying degrees of stone and brick elements. This is further strong evidence against the earlier stone building proposition, as it is extremely unlikely that all blockhouses located around the antenna site, in places with the best defensive lines of sight, would have conveniently had an earlier stone building upon which to rest. The foundation for the eastern extension, when it collapsed much later, did so entirely and cleanly, not continuing under the brick element as it would if it were part of an earlier foundation.

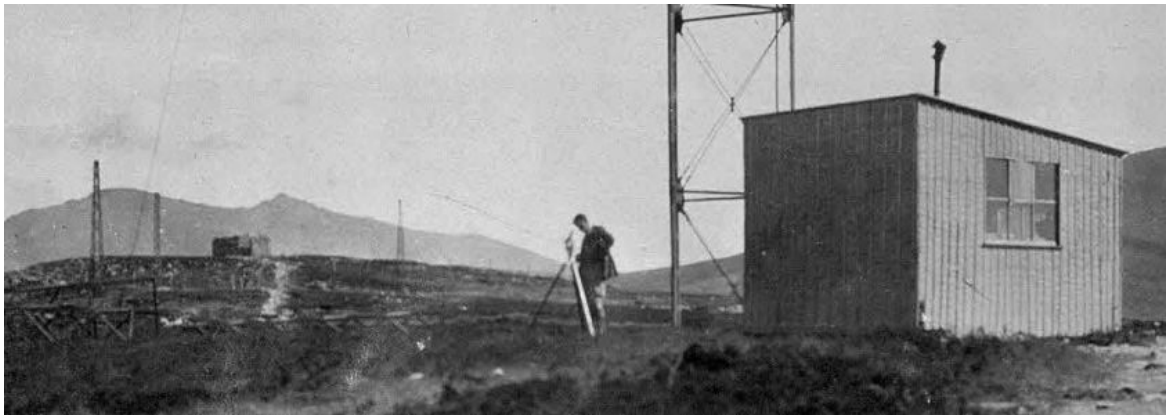
In 1923, we have conclusive evidence of the form and function of the stone element, in that it is seen in photographs 704/x and 706/x within Bodleian Archive folder MS.Photogr.c.243 to be in use by workmen during construction of the new antenna extension array.

H3. *MS.Photogr.c.243, evaluation quality photograph 704/x, showing the brick and stone elements in use for work on the 1923 antenna extension. No guttering (nor space for it) under the roof of the brick element is evident, which clearly drained directly onto the stone element's roof – which also has no guttering.*

H4. *Detail from MS.Photogr.c.243, evaluation quality photograph 706/x, showing the brick and stone element.*

The firing holes of the brick element were blocked-up with cut brick and mortar, which is seen to be clearly different, later mortar from that used for the 1914 bricklaying. All the holes along the western elevation of the brick element are blocked-up. Blocking-up would defeat their original purpose, and so it is strongly suggestive of being done after the end of WW1. All the firing holes in blockhouse 2, the only other still standing, are fully open and show no sign of ever having been blocked. Again, this strongly suggests all the firing holes of blockhouse 5 were fully open until sometime after WW1.

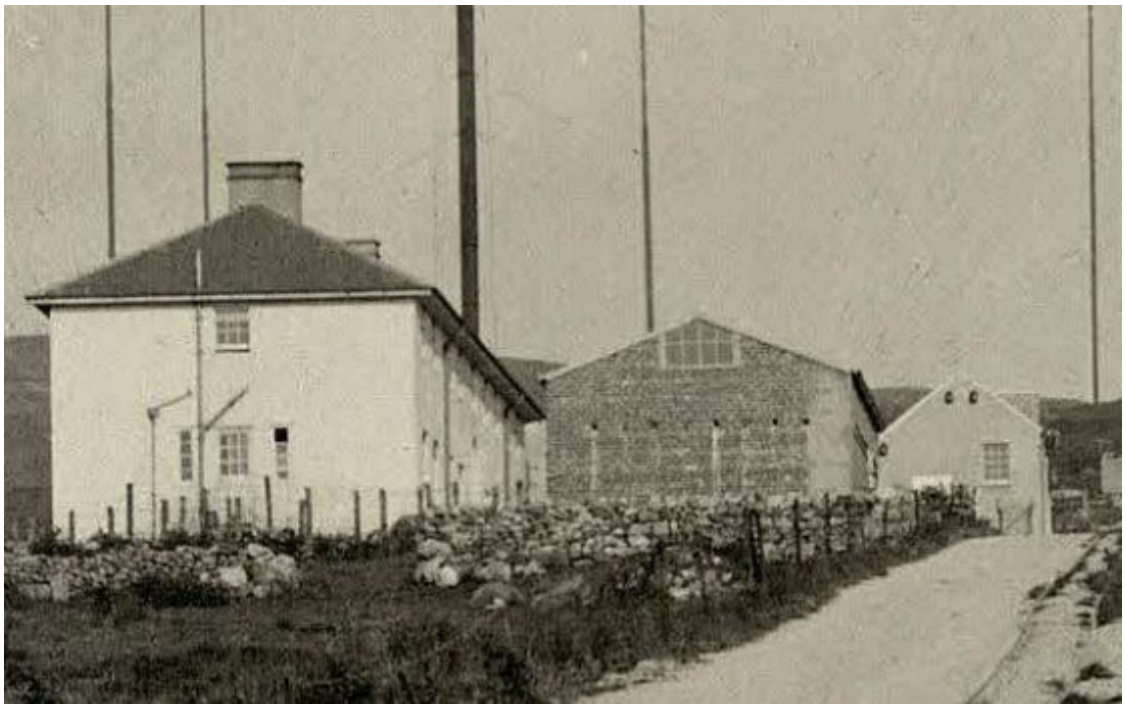
There was no obvious use for the then isolated building between the end of WW1 and the antenna extension work, which began in early 1923; that year seems to be, by some way, the most likely explanation for the sealing of almost all the firing holes. By 1923, as shown in MS.Photogr.c.243, photo 705/x, blockhouse 6, at the summit of Cefn Du, had already lost its roof and was semi-derelict (storms tore the roof off a number of blockhouses almost as soon as they had been built (*Y Drych*, 20/5/1915, p.3). It is therefore possible that blockhouse 5, being similarly extremely exposed, required some renovation before being put to a new use.



H5. *Detail from MS.Photogr.c.243, photo 705/x, showing blockhouse 6, just to the left of the peak of Yr Wyddfa, already in an advanced state of decay by June 1923. Bodleian Special Collections.*

Either that, or the holes were opened up after the 1923 extension work, most likely, in that scenario, during the WW2 period – although as already noted, even then, their view was severely restricted to the point of near-total obstruction by the remnant eastern stone elevation. There was also then no antenna to defend – the station was dismantled in 1939, though the location may have been useful as a lookout. Those firing holes with a clear view over what is, from that position, a much reduced-height section of the eastern stone wall, remain blocked-up.

When the antenna was being extended down the slopes towards Llyn Padarn, the brick blockhouse that remained – it is seen in 1923 to be in excellent condition and still retaining its large, probably upper floor bunkhouse window above the entrance (as the other, larger blockhouses had – see detail at **H6**) - would have been an obvious and very convenient, existing building on a large area of flat ground near Cefn Du summit. Photographs show this was a very busy lay-down area and central hub of the extensive light trackway system.



H6. *Detail, showing blockhouse No. 1, 50' to the immediate west of the engineers' accommodation block. Date ca. 1918; lime weep from the firing holes suggest it has been in position for some years. Almost nothing of the blockhouse remains now, though its perimeter is clear. Bodleian Special Collections, MS.Photogr.c.243, photograph P.2090*

H7. *Blockhouse 2, showing stone base as for all site blockhouses, and that all firing holes remain open and were never blocked. It seems not to have had any use after the end of WW1, adding to the evidence that blockhouse 5's firing holes were blocked simply because of repurposing for the 1923 antenna extension. Most or all of the blockhouses had an open porch in front of the doorway.*

Appendix V.

The Towyn Receiving Station, 'MUV'.

It is not the aim of this work to examine the Towyn station in detail; a proper treatment will appear in a later edition. Gwynedd Archaeological Trust's Report 1302 deals with the non-technical aspects, though it should be noted that where it does tentatively venture into technicalities, there is no evidence for frame or Franklin antennas – mentioned as possibilities at Carnarvon – either on the ground or in the archives. So as not to ignore the receive site entirely, good photographs, many rarely, if ever, seen by the public were found in the Marconi archive in Oxford, and are presented here.

Towyn was not Marconi's originally-intended site for a receiving station. *The Dublin Daily Express* of Tuesday, 10th September, 1912 (p.10) reported that the receiving site "will be at Nebo", 12.9km (8 miles) to the south-west of the transmitting site. According to the 25th October, 1912 edition of the *North Wales Weekly News*, the reason for the change of location was the "unreasonable demands of the holders of certain lands and sporting rights", the loss of the receiving station to a different county clearly the cause of some consternation, underscoring the tough employment situation of the time.

Towyn consisted of an operators' building, housing the receiving positions, together with a large office-type room with keying positions to effect transmission from Carnarvon. Separately, living quarters in the form of what are now called 'Marconi bungalows' were provided, still in existence and good order today. Other outbuildings housed antenna matching/tuning apparatus.

An account of how messages were processed in the course of reception can be found in Vyvyan, 1933 (op.cit., p.62-63); as in much of his poor account, he was simply repeating what had already been written, many years earlier, in *The Wireless World* (July 1914, p.219).

A file in the Bodleian Marconi archive (MS.Marconi 198) reveals very early detail about Towyn, even before final agreement for land acquisition by Marconi's had been reached. Marconi's personal assistant, Henry Joseph Round, was the man sent to conduct early reception experiments at the desolate seaside town of Towyn. Round was an accomplished electronics engineer, contributing significantly to the development of thermionic valves. Round also made the discovery of electroluminescence from cat's whisker wireless detectors, which eventually led to the development of light-emitting diodes that have in recent years come to dominate artificial lighting.

Round was based at the Corbett Arms Hotel in Towyn. His enthusiasm to get things done is abundantly clear in his correspondence with the Chief Engineer (since 1910) at Marconi's in London, Andrew Gray. Gray, according to *Grace's Guide*, conducted operator training and other work at Marconi's Hawaii (Kahuku) station, built at the same time as Carnarvon.

Round, whilst wise enough to appear to await instructions from London, was apt to make his own arrangements, all the same. In a letter to Gray of June 11, 1913, Round writes impatiently:

> "I will not make any change in the aerial system as you instruct – the changes I had in mind however would not have caused any trouble and I shall be glad of instructions to go ahead...For the transmitting tests I have obtained the use of a field next to the hotel. This is entirely independent of any arrangements about the receiving system and will cause no trouble."

Gray, concerned that Round should not cause any antagonism locally, responded on 10th June, 1913:

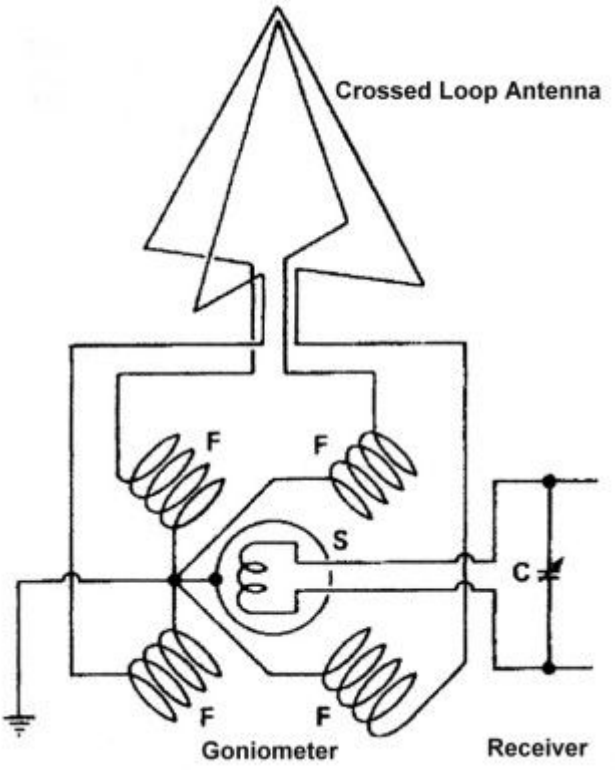
> "On no account make any change in the aerial at present. The contract for the land has not yet been signed, and as there was a good deal of friction in the beginning on account of work being started before permission was given, please do not do anything before the contract has been signed by both parties."

The initial arrangement at Towyn was a single row of five lattice masts, 300' tall, advancing towards the summit of Corlan Fraith hill. Initial tests by Round with low timber poles, which sought to avoid the expense of steel masts, though steel masts were the planned installation, proved disappointing; signals from New York being reported as weak and unreadable under any but the best conditions (Round to Gray, June 9, 1913). Round thundered along with tests, involving various lengths and numbers of receiving wires, and the addition of various inductances ('tuning coils'). Gray remarks, in a response on the following day to Round, that the results indicated there was "nothing for it but to put up the 300 ft. receiving masts originally proposed". The correspondence reveals the 26,000ft wavelength in use by Glace Bay (38kHz frequency) whilst Clifden used 20,000ft (49kHz).

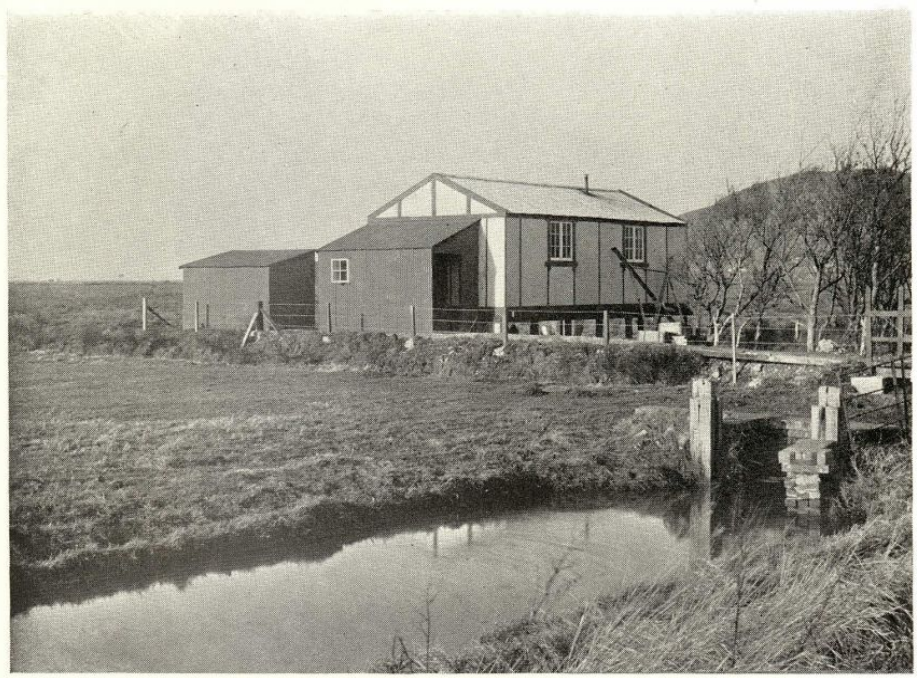
The steel masts eventually installed were of a helical, 'Rendahl' design, supporting two wires from either side of a short arm at the top of the mast – poorly but definitively visible in an archive photo (see **R7**). This was again an inverted-L antenna, aligned on a great circle path of 285 degrees to the New Brunswick (New Jersey) receiving station. The mast nearest the station is seen in photographs to be at a marked offset to the masts further uphill.

A long 'balancing' antenna was installed at right-angles to the main receiving antenna, so that the strong signals from the transmitter could be cancelled out by careful adjustment of signal phasing. Later antennas were of the Franklin, phased 'frame' type, located on the flats a mile to the west of the main station building; the exact location is yet to be determined. Further study on the installations at Towyn is ongoing. The frame masts were timber and 100' high.

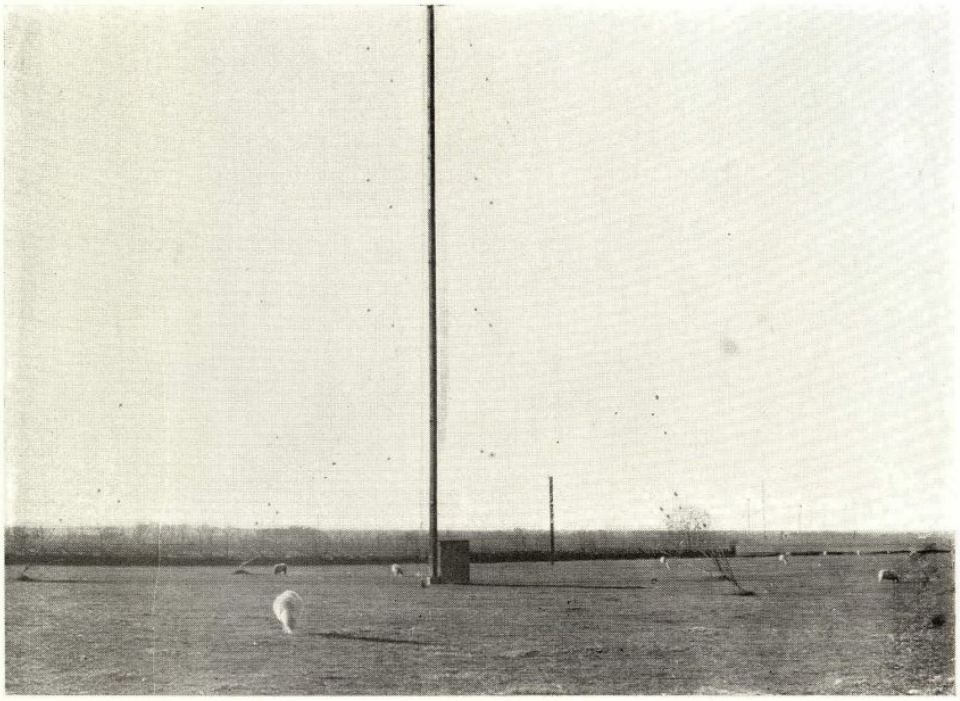
R1. *The main Towyn station building. The lattice mast might have been part of an initially single directional Bellini-Tosi frame antenna, but the details are unclear. Later accounts tell of two Bellini-Tosi directional loops, separated by ¼ wave (i.e. two mast structures separated by that distance, supporting two loop wires each).*



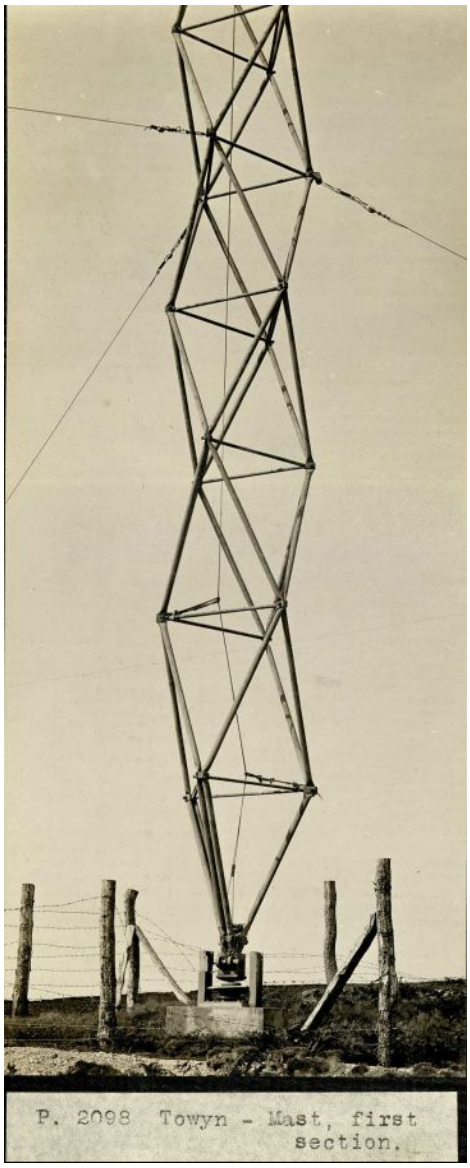
R2. *Schematic of a Bellini-Tosi directional antenna. There seems to have been two of these antennas in a later stage of Towyn.*



R3. *Auxiliary station, centrally housing various control circuits for the later antennas. Ca. 1922 Marconi Co. pamphlet about Towyn, in MS. Marconi 198. Note the channel and high water level on ground only ~2m above OD sea level. A nearby embankment broke, flooding the Marconi station to a depth of three feet, causing "wireless men on boats" on 23/9/1922 – see* **R14**. *(*Daily News (London), *25/9/1922, p.5).*



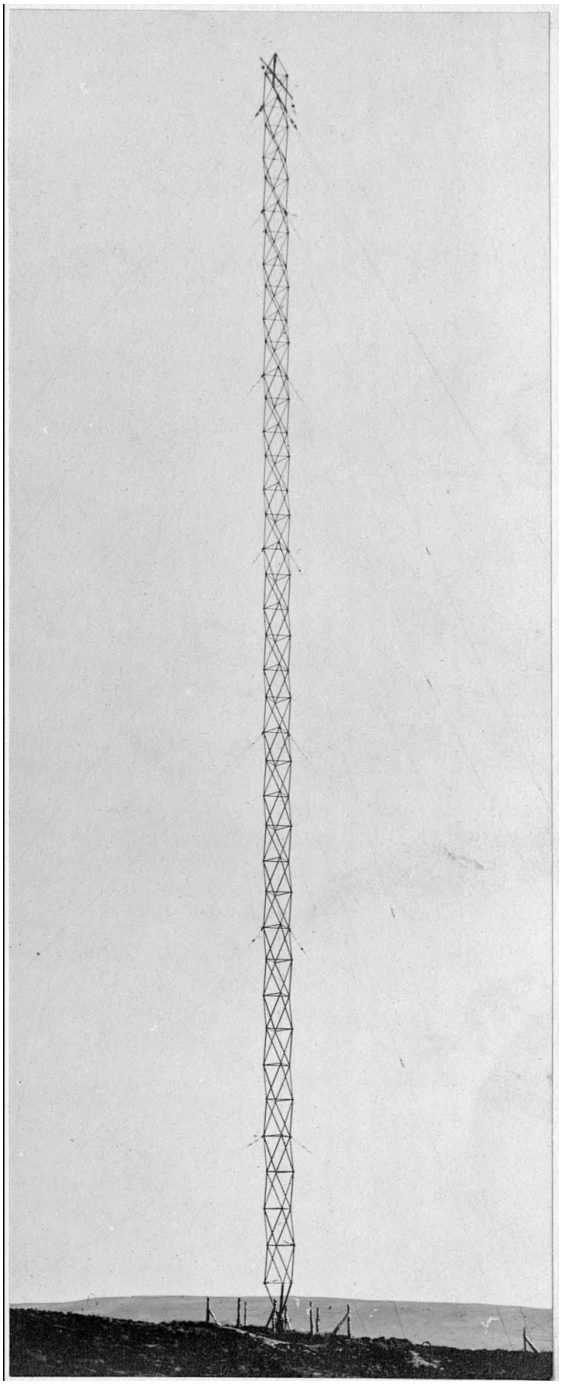
R4. "*Unit aerial" and transformer hut of the auxiliary station, Towyn. This 'Franklin' system utilised four spaced timber supports of 100' height. Two pairs of antennas were used to receive two different transmitters. The unit antennas could be phased such that they were directional. Today an obscure design, its form and operation is slowly being elucidated.* ca. *1922 Marconi C°. pamphlet about Towyn, in MS. Marconi 198.*



R5. *The striking helical 'Rendahl' masts of the first Towyn receive (inverted-L) antenna. Note the pivoting base, highlighting then, as now, the role of carefully-tensioned stay wires to maintain a steady vertical mast. Bodleian Special Collection, MS.Photogr.c.243, photo P.2098. Below: Ragnar Rendahl, 1878-1929.*

R6. *A helical, 'Rendahl' mast, which were standard-issue, high strength-to-weight ratio designs for early Swedish wireless stations, here seen at Härnösand radiotelegraph station, callsign 'SAH', opened in 1916.*

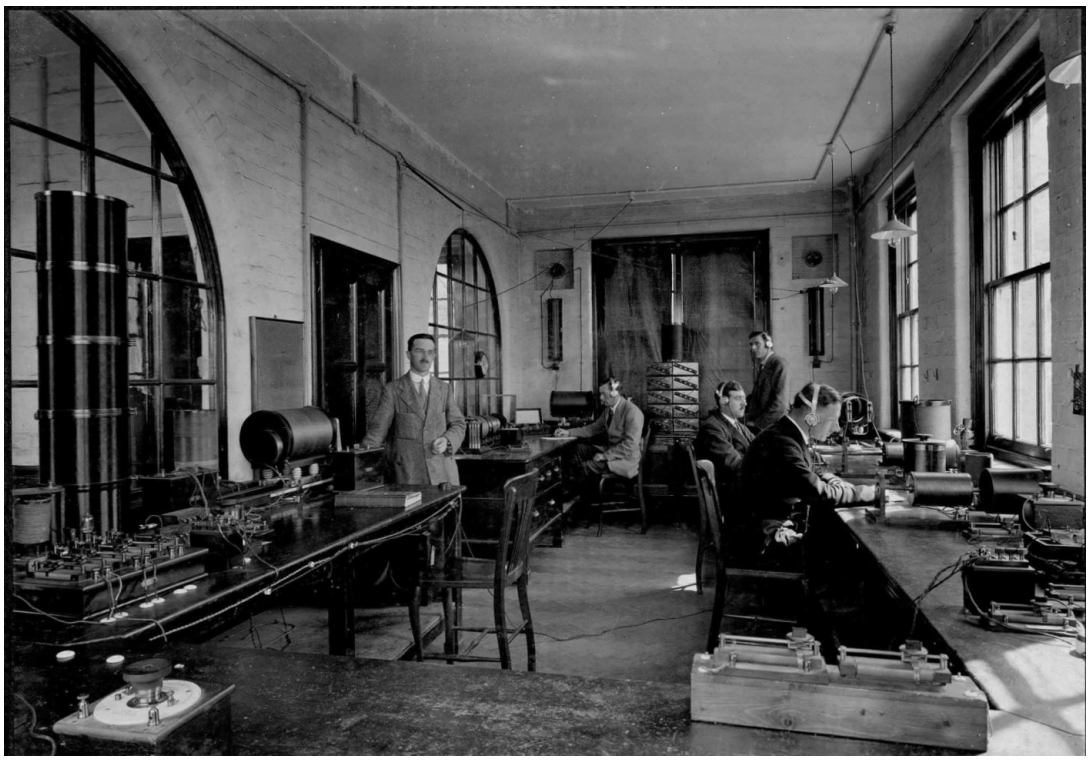
Photo: Telemuseum. Stockholm. Additional information kindly supplied by K.A. Markström.



R7. *Above: full, 300’ length of a Towyn receive antenna support mast, stayed with six sets of regularly-spaced wires. Bodleian Special Collections MS.Photogr.c.243, photo P.2099*

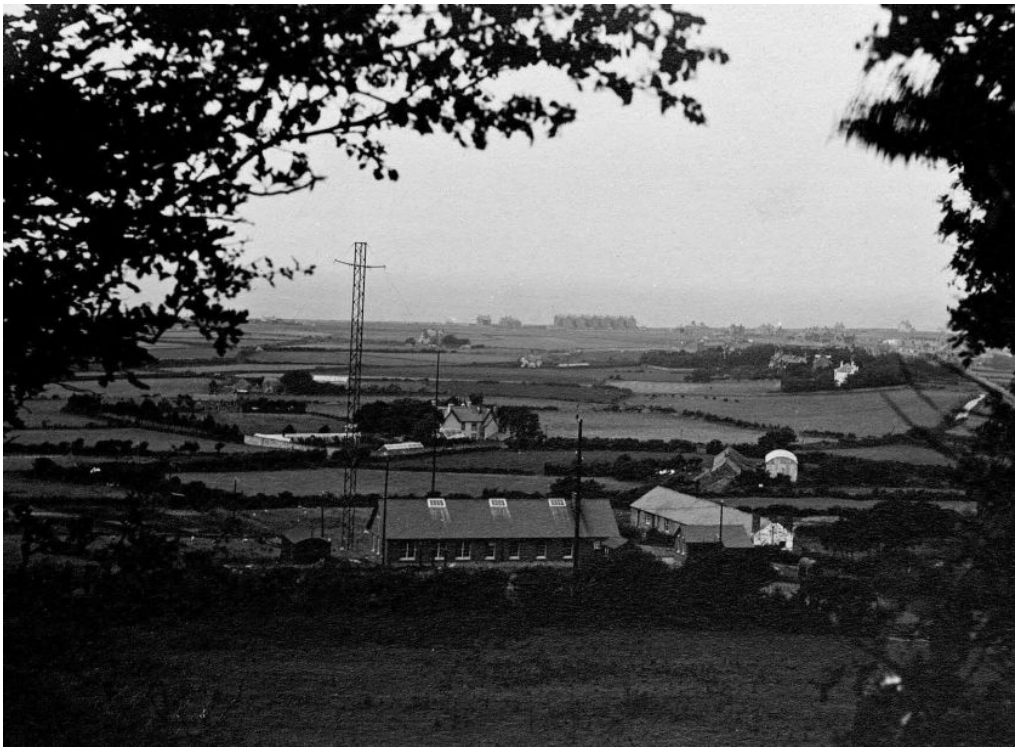
R8. *A worker takes a break at the base of a receiving antenna support mast in this contemplative scene. Note the halyard, which is seen to run inside standoff brackets in other images. Four other lattice masts of the original, 'inverted-L' receiving antenna are seen to run up the hill in the distance. The top of the nearest mast seen in its entirety clearly has a horizontal arm. This supported a single wire either side; contemporary accounts describe it as a "two wire" antenna (Bodleian Special Collections, MS.Marconi.198), though electrically, it was one, connected at a common anchor point and then to the receiving sets. A man in naval uniform bearing the sleeve insignia of Lieutenant looks on, centre right, hinting at a WW1-era date. The mast converges on a tilting bearing. The steel uprights, with roughly-cut oval openings either side of the base mount would almost certainly have been a temporary pivot or securing point for erecting the mast at installation. Guy wires kept the mast vertical. The base remains* in-situ*, but the steelwork is now rapidly dissolving in the salt-laden gales. Bodleian Special Collections, MS.Photogr.c.243, photo P.2097, date unknown, probably* ca. *1918. The distinctive curved field boundary, which is unchanged today, permitted the location to be confirmed as 52.581847°, -4.066318°*

R9. *The keying room at Towyn for the Carnarvon transmitter. Bodleian Special Collections, MS.Photogr.c.243, photo P.2102 (page 7 within original photo album)*



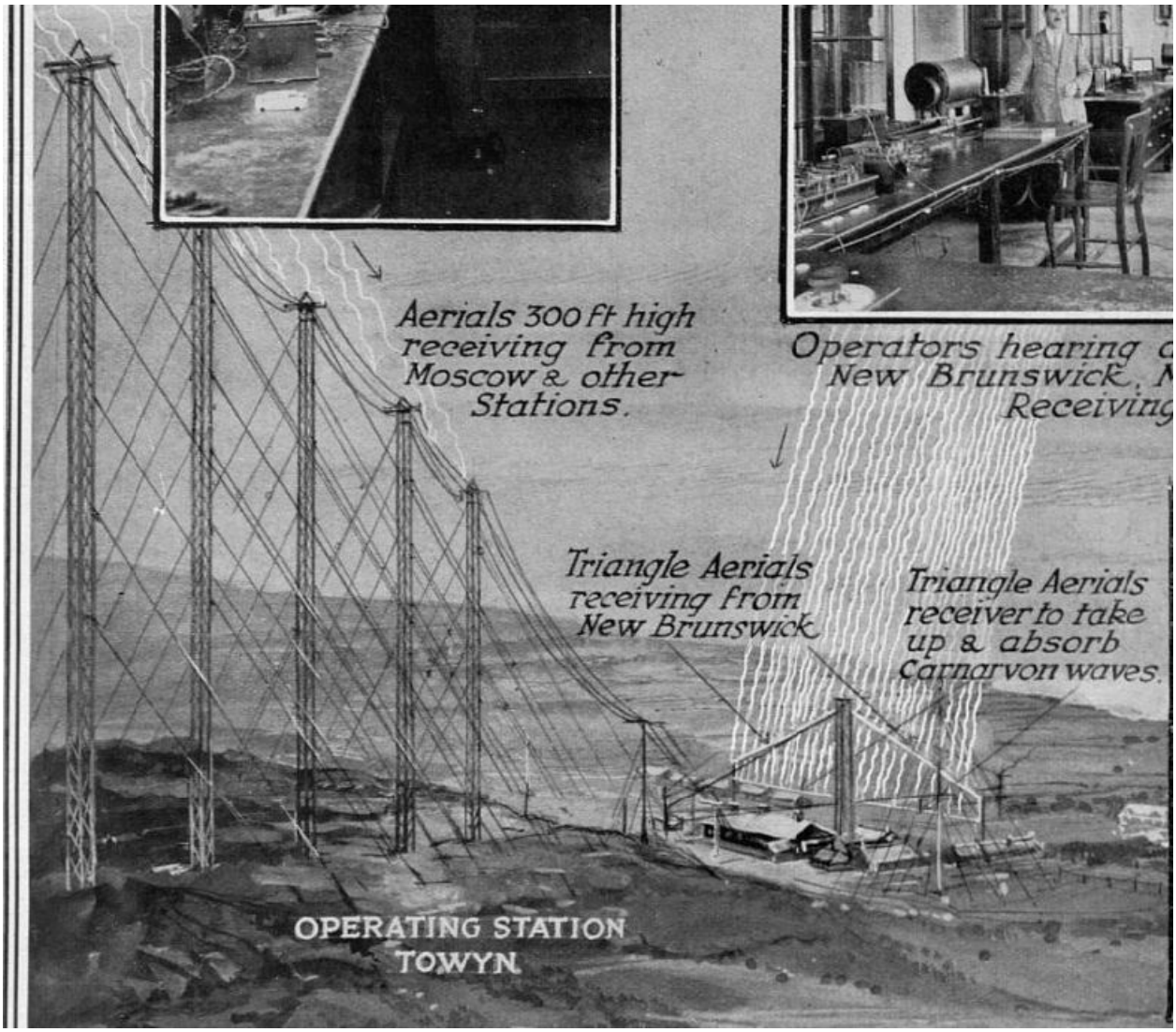
R10. *Towyn receiving room, the sunlight direction through the windows suggesting it was at the western side of the building. Bodleian Special Collection MS.Photogr.c.243, photo P.2106 (page 5 within a separate, original photo album in the same file).*

R11. *Individual operators transcribing Morse transmissions into text at Towyn. The landscape just visible outside is hilly, and thus the view is to the east. MS.Photogr.c.243, photo P.2100.*

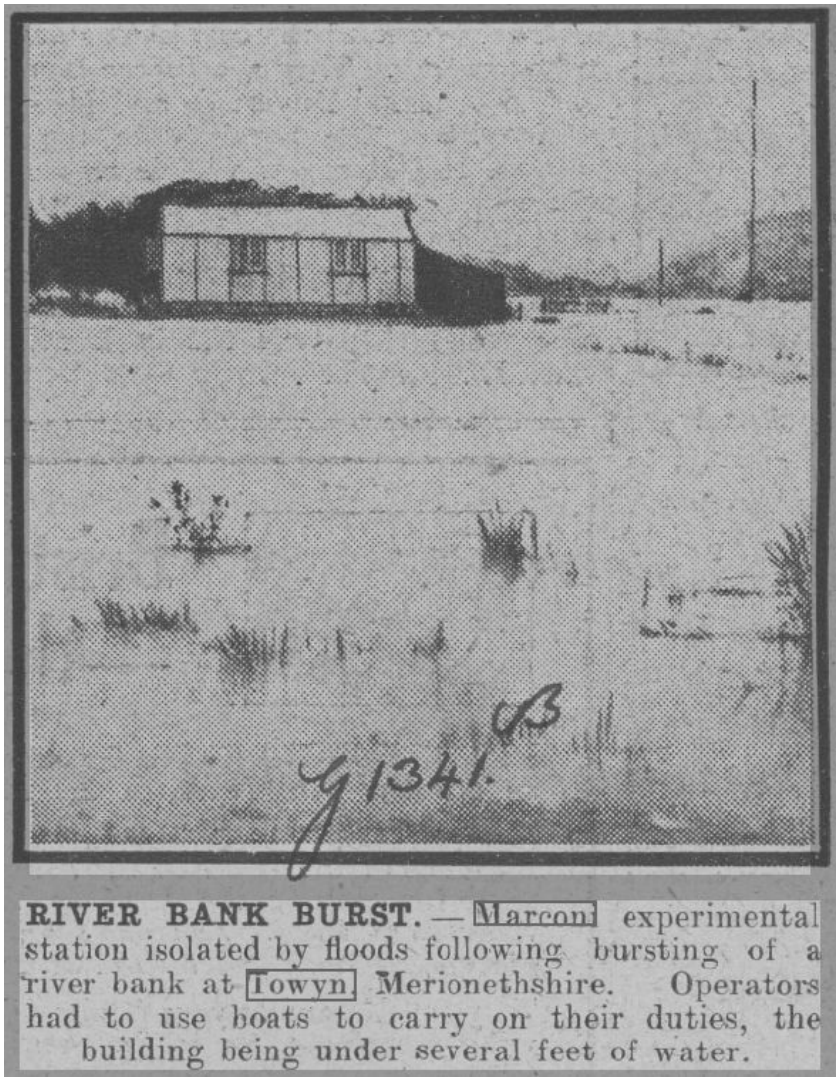


R12. *Looking towards the coast at Towyn receiving station, with a frame antenna to the immediate left of the station (seen dominating the scene at left in* **R1***). Bodleian Special Collection, MS.Photogr.c.243, photo P.2095.*

An important discovery was made within the Saturday, 27th of January, 1923 edition of *The Sphere* newspaper (centre-spread, pp.88-89), of a double-page feature graphic about Carnarvon and Towyn stations. Detail of the antenna masts at Carnarvon – for example, the incorrect steel section tube count for the 400' masts – throw doubt on the detail depicted, but is nevertheless an interesting general overview.



R13. *Rays from distant stations fall on antennas at Towyn in this graphic, signed by its artist, D. Macpherson in 1921, but not published until January 1923. There has been a fair degree of artistic licence taken; the mast spacing on the left has been compressed substantially, and their alignment is to the south-west, not the north-west as is known from a photograph and Marconi company text description to have been the case in reality. Source as per main text.*



RIVER BANK BURST. — Marconi experimental station isolated by floods following bursting of a river bank at Towyn, Merionethshire. Operators had to use boats to carry on their duties, the building being under several feet of water.

R14. *Flooding at Towyn, the worst of which occurred on 23/9/1922. The scene shows the auxiliary hut depicted in* **R3** *(Daily Mirror, 28/9/1922, p.8).*

With receiving facilities by now largely centralised in Essex, the Towyn station site was disposed of in 1924. A notice in the June 6th edition of the *Daily Mirror,* entitled '*Who Wants a Wireless Station?*' (p.2), reported that "eight bungalows, a powerhouse and offices" were "to be auctioned". The *Nottingham Evening Post* of the same day (p.6) gave the same information, adding that Marconi's had instructed "Messrs. Frank, Knight and Rutley" in the disposal.

Appendix VI.

Social Aspects of Marconi's Welsh Stations.

The arrival, almost overnight, of a major element of Marconi's strategically-important communications system in a quiet corner of north west Wales must have been quite an event. The area, whilst obscure to most in the UK, was nevertheless already firmly connected to the wider industrial world through its large-scale slate extraction albeit, by then, in terminal decline (*The North Wales Quarrymen, 1874-1922*, R. Merfyn Jones, University of Wales Press, 1981, p.295). Marconi's wireless station, however, was something that heralded an information age, something beyond digging things out of the ground.

Engineers and operators came and went in significant numbers; there was room for up to 16 staff at the well-appointed Marconi Hall accommodation block at Carnarvon. At Towyn, around 9 operators attended to transmitting and receiving operations. During building phases, and for military protection during WW1, numbers were much higher and, as we shall see, came to be problematic.

S1. *Marconi Hall, the 'hotel' accommodation provided for Carnarvon engineers and operators, who were rotated frequently by the company. A Y.M.C.A. hut was set up alongside in 1915, becoming a hub for community socialising. Image of 17/08/2022.*

The Welsh newspaper archives holds a large number of reports about social interactions at both Carnarvon and Towyn stations, where locals, station staff and military guards alike took enthusiastic part, not least to support one another through wartime hardships. This was facilitated by the Y.M.C.A establishing a hut, complete with billiards table, pianoforte and temperance (i.e. no alcohol) bar, at Carnarvon's Marconi Hall "for the benefit of soldiers" (*Y Genedl*, 6/7/1915, p.3) and, initially, a marquee at Towyn for their typically weekly gatherings, which were evidently extremely popular. *Y Genedl* had earlier carried a report (29/12/1914) expressing relief that the soldiers at Carnarvon had been given accommodation (presumably the blockhouses) for their shelter

and safety, though conditions within the very basic and exposed huts must surely have been rough, to say the least.

Soon after the war had broken out, ladies of the Pwllheli War Relief Working Party, allied to the Red Cross Society, were busy working in support of Marconi station troops, amongst many others. *Yr Udgorn* of November 11th, 1914 (p.3) reported two dozen scarves and two dozen pairs of mittens being sent to guards of the wireless station and Cwm Dyli hydro plant. The individual output of each woman was carefully noted in the report, in a very church collection plate sort-of-way.

At Towyn, days after war was declared, one local – a Mr. Edmunds of Manchester House – was busy "gathering fruit, vegetables and magazines" for the Marconi guard (*Cambrian News and Carmarthenshire Standard*, 4th September, 1914, p.2); calls for donations of games were also made.

Religion was then still a significant element of personal lives, heightened by a time of war and loss. The 21st March, 1916 edition of *Y Genedl* tells how R.E. Owen, recently appointed as a non-conformist Chaplain at the Carnarvon station Y.M.C.A., was "working energetically to make the soldiers happy". A student of the North Wales Baptist College at Bangor, "who, like many other theological students" had "temporarily given up his studies to undertake useful duties in connection with the Y.M.C.A. [at Carnarvon]", reported the 2nd July, 1915 edition of *The North Wales Chronicle and Advertiser for the Principality* (p.7).

At both Towyn and Carnarvon, a genuine 'wartime spirit' was clearly in place, with the community making considerable efforts to lighten the load on guarding soldiers' minds – although boredom seems, by far, to have been the most serious enemy. The soldiers were especially touched by a concert given on 17th December, 1915, by the schoolchildren of Cwm y Glo at the Y.M.C.A. room, reported in *Yr Herald Cymraeg*, 21/12/1915, p.5.

Local religious groups also made use of facilities at the wireless station. On 9th of November, 1916, the Young Women's Christian Society, Carnarvon, held a concert there (*Yr Herald Cymraeg*, 21/11/1916, p.5).

At Towyn, singing (with and without guitar accompaniment), pianoforte-playing, poetry, telling amusing stories and sports were all activities enjoyed there. One evening, to mark the departure of Royal Marines who had been guarding the wireless station, a demonstration of hornpipe dancing and a soloist entertained attendees (*Cambrian News and Meirionethshire Standard*, 17/10/1919, p.7). At both stations, Eisteddfodau were important and regular events, highlighting the extraordinary cultural talents of those who had sometimes received little or no formal education.

Not that it always went smoothly. Great excitement abounded, as reported in the 16th June 1914 edition of *Y Genedl*, as Guglielmo Marconi himself, on an extended visit to his just-completed north Wales stations, was due to preside over the Towyn Eisteddfod Gadeiriol. Perhaps feeling that a dull boilerplate speech about his endeavours in wireless communication wouldn't really cut it at an Eisteddfod, he didn't turn up. But then, neither did the winner of y Gadair (the bard's Chair), leading to the *Llangollen Advertiser, Denbighshire, Merionethshire, and North Wales Journal* of 19th June, 1914 (p.4) calling the whole event "a farce".

The large marquee installed by the Y.M.C.A. at Towyn's Marconi station was reported by *The Cambrian News and Meirionethshire Standard*, 1/10/1915, as having been destroyed by a gale in late September – probably the 23rd of September according to NOAA Central Library synoptic

pressure charts for the preceding week. As a result, by November, a permanent Y.M.C.A. hut was being sought at the station (*Cambrian Daily Leader*, 27/11/1915, p.6).

A later Eisteddfod, of 25th January 1916, held at Capel Moriah (Annibynnol) and reported in the 1/2/1916 edition of *Y Genedl* (p.8), fared much better. It was celebrated as a "successful festival" that included "two or three" competitions reserved for solider-only participation.

Sports were, naturally, also a significant feature of interaction between Marconi staff and locals. A *Caernarvon and Denbigh Herald* article, *et alia*, of February 27th, 1914 (p.5), tells of a "hockey match on roller skates" on either 24th or 25th February, 1914 – articles disagree – at the Pavilion Skating Rink, between a Marconi team and the Carnarvon Celts. A "fast and exciting game" ended in a draw of three goals each.

A shooting match was held on Saturday, 11th September, 1915, between members of the Barmouth Volunteer Training Corps and the Marconi Guard at Graigfach shooting range. For the shorter-range contest, with a bullseye diameter of 1", the Marconi guards had a total score of 283 against the Barmouth volunteers' 230. On the 50 yard contest, with a 2" bullseye, the Marconi guards did considerably better, beating the Barmouth volunteers by 285 to 188 (*The Barmouth and Country Advertiser and District Weekly News*, 16/9/1915, p.6).

When it came to football, the Marconi XI team didn't do so well. In a post-war match of Saturday, 13th of September 1919, at Sandilands Park (Towyn), Towyn Rovers scored 4 goals to nil against the Marconi XI team (*Cambrian News and Meirionethshire Standard*, 19/9/1919, p.7). A few weeks later, on Saturday, December 20th, the Marconi XI team fared even worse, losing by 6 goals to nil against Abergynolwyn at Towyn. It is not known for how long after the war the guards remained.

A lovely cameo of local life comes from a report in the *Cambrian News and Meirionethshire Standard*, 16th of July, 1915 (p.8), of an "outing" on the previous Saturday (10/7/15). Wives and children of the Marconi guards were entertained by Mrs. Fuller, Penymaes. 3 o'clock tea was served at Brynmor and was much enjoyed by all. Sports contests were held, in which "all the children and the majority of the adults" took part.

It seems to have taken a short while for the authorities to realise Cwm Dyli needed military protection. Not until the 5th of December, 1914 – over three months after the commencement of hostilities – did the press report "25-30 year-old volunteers, or soldiers" arriving to guard the power station and Llyn Llydaw, the source of energy for the hydro plant. A hut was reported as being erected to accommodate the guards near the lake, day and night (*Baner ac Amserau Cymru*, 5/12/1914, p.2). An advert for men "not under 38 nor over 50 years of age" to come forward to protect the Towyn station seems not to have appeared until 26th February, 1915 – over six months after war had broken out.

The Marconi site guards often played their part in community affairs. Numerous reports appear in the press of the time, telling of Marconi station soldiers supporting bereaved families through attendance and, sometimes, participation at funerals. *Yr Herald Cymraeg* of 7th November, 1916, tells us how numerous Marconi station soldiers were present at a packed church for a service to remember [Second Lt.] Kelyth Pierce Lloyd-Williams, 12th Welsh Regiment [he is listed by the CWGC as 17th Bn.], son of Dr. W. Lloyd-Williams, J.P., and Annie Lloyd-Williams of Llwyn y Brain, who was killed in action on 17th October, aged 21 years. Lloyd-Williams was buried at Maroc British Cemetery, Grenay, France – grave I.K.12 (Commonwealth War Graves Commission records, online).

On another occasion, *Y Genedl* of 17th April, 1917 (p.3), reported on Marconi station soldiers bearing the coffin at a packed Llanrug cemetery, on Easter Monday, of Griffith J. Griffith, Ty Capel Clegir, Llanberis. Griffith was a young soldier who died in Britain of wounds sustained in France in 1916, as a note of thanks from his family to the community for their support details, later in the same edition (ibid, p.8)

All was not as delightful as one might initially expect from the newspaper reports of jolly fêtes, sports and community support. Behind the scenes, back at the Towyn Marconi station camp, conditions for the large number of men had deteriorated to a very unhealthy degree. By late spring, the Medical Officer, Dr. Edwards, had visited the camp and reported on the "sanitary conditions being entirely unsatisfactory". Dr. Edwards complained that conditions at the German PoW camp at Bala were "a palace" in comparison to conditions at the Towyn Marconi camp. The military authorities and Marconi's were to be approached for improvements (*Cambrian News and Meirionethshire Standard*, 21/5/1915, p.3).

Matters then developed into something of a scandal.

The same newspaper (ibid., 18/6/1915) then carried a lengthy report of a discussion about Dr. Edwards' findings by the local Urban Council. It is best reproduced, with the addition of some paragraphs for clarity, in full:

Towyn Marconi Camp.

The Clerk said that at the previous meeting of the Council, Dr. Edwards presented a report with regard to the conditions prevailing at the Marconi station camp at Towyn. That report was forwarded to Capt. Fuller, officer in charge, and Dr. Edwards arranged with him to pay another visit to the camp.

Accordingly he went to the camp on Saturday following the Council meeting, but was stopped by the guard, who required his passport or ticket of permit. Dr. Edwards explained that he was there by invitation of Capt. Fuller, and a message was sent to that officer to that effect. Dr. Edwards, however, was still refused admission and so could not carry out the inspection he had been instructed to make.

No reply had been received from Captain Fuller, and he had not even acknowledged receipt of the first report.

Under the Local Government Board order a copy of the report should have been sent to the War Office and the local Government Board, but he felt that in this case it would be better to send it to Capt. Fuller alone.

It was a rather unhappy business that he should have refused Dr. Edwards admission to make an inspection after he had made arrangements at his (the Captain's) own request. He was afraid that some little feeling had been created by the reporter using the word scandalous in his report; but Dr. Edwards was not responsible for that.

Dr. Edwards said he had nothing to add, except that he adhered to every word he had used in his report and that the condition of things were exactly as he had stated. He understood that some

things had been done at the camp since the last meeting of the Council, but he considered there was grave responsibility on the Council.

At the time of his first inspection he was looking forward to the summer when the flies gathered on collections of refuse. He had referred particularly to a ditch which had been filled in and the contents of which were oozing out into a disused river with stagnant water at the bottom. The odour was then certainly far from healthy. He told Capt. Fuller that he had no right to refuse him admission as there was an order issued by the War Office placing the responsibility for sanitation on the local sanitary authority which stated that any expense incurred by that authority would be refunded by the War Office.

Captain Fuller said that he knew nothing of the order and he (Dr. Edwards) replied that someone at the War Office should have informed him. When he inspected the [German PoW] Bala camp he was met by the Commanding Officer and made his report showing the defects. Within forty-eight hours, everything was rectified. He showed the circular to Captain Fuller; but still he treated the matter as if the whole district was under martial law. Whether it was or not he (Dr. Edwards) did not know, but he had not heard anything about it. He still maintained that the conditions of things he found on his visit and reported to the Council would be dangerous to people who had houses near the camp when the flies came in summer.

As far as he was concerned, unless the Council took action, he would call a meeting of the County Health Committee to deal with the matter. —Mr. E.L. Rowlands: It appears to me that is our duty to uphold the Medical Officer. —The Chairman: Of course.— Mr. W. Jones Hughes: The health of the whole district is in danger. Have we power to visit the camp?—The Clerk said there could be no question about that; but refusal may be rather unfortunate if reported. He suggested that the report should be forwarded to the War Office without comment, but with an inquiry whether the order issued by the Council did empower their medical officer to go to the camp without special permission. Personally, he thought there was no question about it. —Mr. John Rees asked if there had been any delay on the part of the Council; and Dr. Edwards replied that he wished to make an explanation, in reply to a letter from a medical practitioner published in the Press. Previous to April, 1915, he had only had power to visit a camp with the permission of the officer in charge; but in April last a news order was issued under which he was authorised to make inspections. His visit was paid during the first few days of May and he thought the gentleman responsible for the letter should have spoken to him first.—On the proposition of Mr. Ffestin Williams, it was agreed to forward the report to the War Office and to the Local Government Board.

At both Carnarvon and Towyn, affairs of the heart inevitably took shape, in some cases leading to marriage and, in others, to tragedy.

In midsummer, 1913, Harold Borlase Triscott Childs, Marconi's supervising engineer during construction of Carnarvon, became engaged to marry Miss Enid M. Williams, only daughter of Y Parch. (Rev.) R.A. Williams of Ficerdy, Waenfawr. Childs was the only son of John F. and Mrs. Childs, The Old Barbican, Loose, Cornwall (*Y Llan*, 13/6/1913, p.5). No doubt rather excited by the summer's events, a few days later, on 16/6/1913, Childs was fined 10s plus costs for driving at excess speed (between 22 and 25mph, a Superintendent Williams asserted – with no means of verifying such a precise claim) through Pool Street, Caernarfon. Childs said he didn't see the officer put out his arm to stop him (*Liverpool Daily Post*, 17/6/1913, p.8).

The subsequent marriage of Childs and Williams, as reported in 21st November, 1913 edition of *Y Llan* (p.2) was, involving as it did a professional engineer from outside the local community and a well-connected vicar's daughter, a major event in the area.

The report tells of Waunfawr being full of "multi-coloured banners". The weather "turned foul, but even so, a large crowd came to Eglwys St. Ioan to witness the union". The bride wore "a costume of crème Bengaline silk, with ermine collar, her hat of black velvet with crown of crème blocke and ostrich mount. She also wore a "pretty necklet, a gift from the groom's father". The maid, Miss Ethel Mathews (Deganwy), wore a dress "of champagne colour with pink collar and trimming, with a black velvet hat with mount and pink rose". Miss Pritchard, daughter of the Rev. O.G. Pritchard, who assisted in the church ceremony, carried a "bouquet of flowers". The church was "beautifully decorated for the event by Mr. J.E. Greaves [this would appear to be John Edward Greaves, inheritor of the Blaenau Ffestiniog slate mines, underscoring the social status of Williams' family]. After the ceremony, a feast was held "in a marquee near the Vicarage". Amongst the long list of well-wishing speeches given was that by a "Mr. Burrows, one of the engineers at the Cefndu [sic] wireless station". Notes of congratulation, presumably sent by wireless, were read by senior engineers and other staff at the Marconi London office. A gift was given by "Mr. G. Marconi and also by the staff at the Cefn-du [sic] Wireless Station".

By the time Enid William's mother died on the 28th June, 1914, she was in British-occupied Egypt, where her husband was almost certainly engaged in wartime wireless work. Harold Childs received his Commission in the R.F.C. just over a year later.

Over in Towyn, *The Wireless World* of January 1917 (p.808) expressed hearty congratulations to a "Mr. A. [Arthur] Pink, Chief Operator at Towyn wireless station, who was married on November 11th [1916] to Miss. Meir Iona [sic] Roberts. The ceremony was conducted at the English Calvinistic Capel [sic], at Aberdovey, Meirionethshire, and the honeymoon was spent at Barmouth." The Free BMD website, accessed 13/09/2022, confirms this (Vol. 11b, p.206 of the Machynlleth District Register for October-December, 1916).

With workers suddenly appearing from afar on the slopes of Cefn Du, transient relationships came to pass. Maggie Owen, of Castle View, Waenfawr, gave birth to a child who subsequently died. Burial costs were, then as now, considerable and Ms. Owen pursued the father, Henry Elliot, of 25 Simpson Street, Battersea in court. The case came to turn on whether or not the child had been born alive. With Ms. Owen's family doctor supporting her claim that the child had been born alive, with "a large number" of other witnesses agreeing, Elliot was ordered to pay £7 7s (£2,710 at 2021 prices using the labour earnings deflator (measuringworth.com, accessed 07/11/2022)) plus costs to Ms. Owen (Caernarvon and Denbigh Herald, March 19th, 1915, p.5). It is interesting to reflect that houses in Simpson Street, Battersea, are currently selling (late 2022) for an average of just over £1 million.

Both Carnarvon and Towyn saw a few incidents of various sorts, trivial and serious. Boredom was clearly a big factor at both stations, as the rather eager-for-action, wishful-thinking of the Carnarvon guard having "definitely heard an aircraft one evening" – with no further incident – tended to suggest in a report in *Y Cymro* on 27th January, 1915 (p.10).

Just six days after Britain declared war on Germany, no lesser force than the Machynlleth Boy Scouts were called upon to protect Towyn station. A message was received on 10th August, 1914 by the Scoutmaster, C. Hall, from Chief [Scouts] Commissioner, Roland E. Philips, "to gather as many boys as possible" to "protect the Marconi Station". Four of the head boys and the Scoutmaster headed for the Post Office to await further instructions. By the time they arrived at the Post Office, a telegram had already been received that, not altogether surprisingly, "the services of the boys would not be required as the War Office had decided soldiers would be necessary" ('Smart Work by Boy Scouts', *The Cambrian News and Welsh Farmers' Gazette*, 14/8/1914, p.5).

An incident involving guns at Carnarvon occurred on the night of Wednesday, 2nd September, 1914 – less than a month since war between Britain and Germany had been declared. The 04/9/1914 edition of the *North Wales Chronicle and Advertiser* ('Mysterious Night incident', p.8*),* told of how "the Territorials who guard the station turned out and shots were fired by them in the darkness", with no further details being provided. Despite a nebulous claim that the wireless station had "been tampered with", this seems to have been nothing more than an over-reaction to not very much. A warning was issued at the conclusion of the brief report that anyone approaching the station, by day or night, would be challenged and, if the reply was not satisfactory, were liable to be fired upon. This public messaging may well have been the whole point of reporting the supposed 'incident'.

On 13th May, 1915, a German student was convicted under the Defence of the Realm Act, 1914, at Llandudno Magistrates' Court. Heinrich Grenwald, from Boulogne, the son of a director of insurance companies, was 20 years old and had come to Britain about a year earlier.

When war broke out, Grenwald was unwell, staying in Britain and being registered as an enemy [under the Aliens Restriction Act, 1914]. He subsequently moved to Conwy but, in August [presumably quite late in the month], was moved [i.e. arrested and sent] to the camp [for 'enemy aliens'] at Queensferry.

When he was released by the Home Secretary in January [1915], he moved to Llandudno, where, apart from a spell in Capel Curig, he had since remained.

The defendant was convicted for possession of a map of Llanberis, which included the area of the Marconi wireless station at Waenfawr. The Chief Constable stated that he, as chief registration officer, had been asked by the defendant for permission to keep those things shown to be in his possession.

The defendant stated that some of the items had been in his possession in Oxford long before war broke out. The defendant was fined £10 plus costs and was bound over not to keep such things in his possession again.

The Defence of the Realm Act came to spoil a man's holiday near Towyn in the summer of 1915 (*Y Dydd*, 25/6/1915, p.4). Edward J. Chambers – a Justice of the Peace, no less – had come for a break from Dudley to the area and had started to make a sketch of the mountainous surroundings.

Unfortunately for Mr. Chambers, his sketch included the hillsides where the Marconi receiving antenna was located – although he had chosen to omit those structures due to their adverse impact on the view.

A Private Socket of the Marconi station guard, off for a swim in the sea, “saw the sketching being done near a hut and was alerted to the same by a civilian”. Chamber’s name and address were noted, and he was later charged by Sergeant David Jones under s19 of the Act in making a drawing without authority. Chambers, an engineer by trade, said that he often came to Aberdovey [sic] to stay. Perhaps unsurprisingly, given he was a minor establishment figure, Chambers’ case was thrown out, but the sketch was confiscated by the authorities for the duration of the war. The public were warned that no-one was allowed to render a depiction of the area.

A rather amusing incident took place on – unlucky for the people involved – Friday, August 13th, 1915, as reported by *Yr Herald Cymraeg* (21/9/1915, p.8).

The first case was against Robert Griffith, 11 Vaynol Cottages, Llanberis, who was accused of buying ‘slippers’ (i.e. slip-on shoes) from a soldier by the name of John Jones, serving at the Marconi station on August 13th. Griffith bought them for one shilling (about £18 at 2021 prices, using the labour value deflator). The defendant was fined five shillings (about £92 at 2021 prices).

The second case was that brought by the Police against Edward W. Pritchard, Snowdon Street, Llanberis, being an allegation of receiving a pair of shoes from a soldier by the name of Private Robert Lloyd Roberts. Pritchard denied the charge, but was fined £1 (about £369 at 2021 prices, by the labour value deflator).

Coastal north Wales can be a bit depressing in the depths of winter. This, and the lack of anything much to keep the men occupied most of the time, led to a few cases of being absent without leave at both Carnarvon and Towyn. On 14/4/1915, *Y Dinesydd Cymreig* gave a brief report on two Marconi guards – Henry Jones and Thomas Jones, both of Caernarfon, being absent from the Carnarvon wireless station. They were handed over to military authorities. *The Cambrian News and Meirionethshire Standard* of 18th June, 1915, reported on how national reservist, Private David Jenkins of Frankwell (Shrewsbury), was charged with being AWOL from the Towyn Marconi station guard. Jenkins was handed over to a military escort. On December 19th, P.C. Edward Humphreys arrested Pte. J. Gough, who was AWOL, in uniform, in Machynlleth at the time. Gough was handed over to military escort, and P.C. Humphreys had a 5s reward recommended to him for the arrest.

Another case involved a Pte. William Sloan, a guard at Carnarvon station, accused of drunkenness in the town on the evening of 21st October, 1915. A special court hearing the following day found Sloan guilty, being released upon payment of costs. No fine was recorded as imposed in the article appearing in *Yr Herald Cymraeg* of 26/10/1915 (p.5).

Spies also featured in the story of the north Wales Marconi stations, suggested by one newspaper as being the prompt for military protection around both.

According to the September 17th, 1914 edition (p. 2) of *The Amman Valley Chronicle and East Carmarthen News*, in an article entitled ‘German Spies in Wales’, “German military officers of high standing” had “manifested quite unusual interest in these public structures [including the Menai Strait tubular bridge]”.

It continued, “One of these German officers was the guest of a leading public gentleman in the county.” On more than one occasion the host missed his guest, who remained away for some hours,

making some apology on his return. The host, however, subsequently discovered that his guest had on these occasions visited and very carefully inspected the Marconi wireless station, the great power station [Cwm Dyli hydro scheme] on the slopes of Snowdon from which the Marconi station derives its electric power, and the great tubular and suspension bridges crossing the Menai Straits [sic]."

"On the outbreak of the present hostilities the host recalled the very remarkable though at the time apparently harmless behaviour of his German military guest. It is now regarded as possible that last year's visit was made for a definite purpose, that detailed plans of the Marconi station and the tubular bridge and their environments were made during their visit, and that both would be among the first objects of attack by German air craft should these be able to reach the West Coast.

A serious fire broke out at Carnarvon station on Monday, 14th of November, 1921, as recounted at some length in *The Western Mail* of 16th August, 1921 (p.3 or 5, indistinct). The Caernarfon Fire Brigade was alerted by telephone, and the town bell was rung to summon the firemen. By the time the brigade arrived, station staff has already extinguished the fire with a hose. Damage to the building was extensive, but the transmitters and associated apparatus were saved. Nobody was hurt. Local people were reported as gathering at Twthill (in Caernarfon town), where a "splendid view" of the fire was had. The cause of the fire was unknown at the time of the report.

The Towyn station played its part in early wireless signals interception. The incident involved Joseph King, a Liberal Member of Parliament for North Somerset. King was a member of a left-wing dominated Liberal/Labour group – the Union of Democratic Control – who were critical of secret international diplomacy outside of democratic scrutiny, and its perceived part in causing the outbreak of WW1.

King, a pacifist and opposed to conscription, was a supporter of the Bolsheviks, blaming the Mensheviks for the revolutionary violence in Russia, and the British government for encouraging them.

King, according to a piece in the 27th October, 1916 edition of the *Abergavenny Chronicle*, had sent information about "the supply and condition of war material" to George Raffalovitch in New York. This would appear to be the same Raffalovitch, a leading figure in the Ukrainian independence movement of the time, who had fled to America after being accused in Britain of having sympathies with Germany.

A *New York Times* news item of Friday, October 20th, 1916, provides much more detail than given by the British press. The subheading summarised that the story passed by King to Raffalovitch was "Probably About a Big Munitions Explosion". This, King had said in his letter, was "the greatest explosion the world has ever seen". He sent it to New York on August 20th, from London. By September 3rd, it had made its way into the American press, and the letter "almost verbatim" made public.

The explosion referred to was that caused when a German aircraft dropped a bomb onto a munitions dump behind British lines in France. The loss was said by King – rejected as "very largely and seriously exaggerated" by the prosecutor – as amounting to £25,000,000 worth of munitions and had "compelled the British to stop their drive on the Somme".

Towyn's role in all of this came to pass when, on September 7th, four days after publication in New York, the story was sent by wireless from New York to Berlin, being intercepted by operators at the Towyn receiving station.

Under Regulation 18, Defence of the Realm Act, 1914, King was fined £100 plus cost of 25 guineas – equating to a ~£7125 fine and £356 costs at 2021 prices – but was spared a prison sentence. This prompted the *Daily Graphic* to note, acerbically, that there was "one law for lieges and another for our legislators". It went on to opine that "there ought to be an appeal to the court of public sentiment" – the kind of outrage we still hear in the tabloid press, today.

At a time of war, there was much concern about anything that might attract the attention of the enemy. On 21st April, 1916, *Y Dydd* reported on a case at Caernarfon Magistrates' Court of four boys from Moel Tryfan and two boys from Ceunant, being convicted of starting bonfires on the hills of the area, the smoke and flames of which was visible from the sea. The Chief Inspector, E. Williams, said his officers had encountered considerable difficulty in extinguishing the fires. The two boys from Ceunant had started their bonfire near the Marconi wireless station, and that the Chief Inspector "considered such a thing to be very serious". All six boys were convicted and ordered to pay 5s costs – about £84 at 2021 prices.

Lawbreaking also gave rise to some comical accounts. An incident of trespass at Towyn was reported in *The Cambrian News and Meirionethshire Standard* of 10th September, 1915, which is worth reproducing in full:

> 'Soldier's Trespass. — Private Edward Tudor, Newtown, one of the Marconi guard, was summoned for having trespassed in pursuit of rabbits on Caethle land without permission on August 11th. — Ernest Pratt, keeper, Penybont, said defendant told him he wanted a couple of rabbits to send home and had several wire snares in a bag. Defendant had also told him that he had caught 400 rabbits since he had been with the guard. "My father," he added, "is one of the best rabbit catchers in the country." He also said that he wanted his discharge, as he might as well spend a month in prison as at the Marconi Station. Several complaints had been made about Tudor trespassing. — Questioned by defendant, the Keeper said he saw defendant in the act of setting a snare. —Defendant: You are a fibber. I did not intend to use a snare. These snares have not been used for six weeks. I had been to fetch them, and when I was coming back I went up to pick up a mushroom. — The Keeper: I was watching you. — Defendant: I was watching you, too. (Laughter). Perhaps I am cleverer than you are at rabbit-catching. You would look much better in khaki. — The Clerk: Have you got the mushroom with you now? — Defendant: No, it happened to be a blind ball. (Laughter). — The Keeper said mushrooming was often given as an excuse by trespassers. — Defendant, in reply to the Bench, admitted that he had no permission to be on the land. He asked for leniency, as he had volunteered for foreign services and might be called away any day. — A fine of £1 was imposed and the Bench intimated that future penalties would be severer.'

More amusement came about when locals in Newborough, Anglesey – just over the Menai Strait from Caernarfon town – thought their big moment had come in apprehending the enemy. In a beautifully colloquial, light-hearted title, 'Dal Germans' ('Catching Germans'), *Yr Herald Cymraeg* of 27/7/1915, p.6), reported how two men had been found amongst the sand dunes of Newborough,

their protests and explanations being disregarded until it eventually became clear that the ‘dau Sais’ (‘two Englishmen’) were men from the Marconi guard who had encountered difficulty when out with their small boat in the bay. The locals may well, as was still relatively common then, have been lacking in English, hence the delay in understanding the men’s protests. The paper thought it better, all the same, to have been safe than sorry.

When the Admiralty took over Marconi’s wireless stations for the duration of the war, Marconi staff became, if indirectly, workers for the government, operating and maintaining a critical piece of wartime infrastructure. But this didn’t stop bureaucrats being as difficult and ridiculous as usual.

The men at Carnarvon were all skilled and specialised in their various roles, not least those who attended to maintenance by climbing the ladders inside the 400’ antenna support masts. It wasn’t a job that many could do.

Because of their skills, they were needed at the station, to keep things going so that the government’s requirements – the maintenance of communications with ships and abroad without interruption – were met.

This is why Lt. Woodward, the senior officer at Carnarvon, had applied a few weeks earlier, in a case adjourned at the Caernarfon tribunal of Tuesday, 27th June, 1916, for five members of the Marconi wireless station team to be exempted from active service abroad, entitling them to remain at their work and wear the ‘On War Service’ badge. When the application came to be considered in early August, Lt. Woodward explained that three of the men were mast climbers, the fourth was a labourer and the fifth, a storekeeper. Lt. Woodward made his point that, as indirect workers for the Admiralty, all the men were engaged in work of national importance. All five were granted permission to remain in post at the station. Another two Marconi workers, Hugh Jones, Gardd Elen, Waenfawr, an assistant engineer and Morris Williams, Caeathro, a driver for the company, had their certificates of release from active duty rescinded, presumably having been exempted at an earlier stage. An advert subsequently appeared on the first page of *Yr Herald Cymraeg* (“Motor Car Driver Wanted”) of 29th August, 1916, insisting applicants “must be ineligible for military service”, Marconi’s clearly seeking to avoid further disruption to their transport arrangements.

The government’s temporary takeover of the Carnarvon station prompted a degree of outrage amongst local slate quarrymen, who found themselves in very hard times as that industry continued to collapse and more quarries closed. Although the Marconi site had been briefly seen as offering work for many, with planned building extensions (built by Llanwnda contractor, Richard Jones) seen as offering yet more employment opportunities (*Y Genedl*, 6/7/1915, p.8), it barely scratched the surface of countering mass job losses suffered in the slate industry.

A meeting of the Arfon County Council of March 11th, 1915, of which R.M. Greaves, a major Blaenau Ffestiniog slate mine owner and local bigwig, expressed concern about the industry. In a discussion with striking parallels to concerns of the modern day, the discussion spoke of “surprise” at how the government was ignoring the domestic slate industry and accepting alternatives “not made in this country”. It was noted how the Marconi station buildings (early extensions to the transmitter hall) would be roofed in “zinc sheet” and not slate, something that struck the meeting as entirely unacceptable, earning the government the stinging criticism that “it was the worst offender”

in aiding the slate industry's demise, especially when it had occupied land on which slate quarries had been closed (the eastern end of the Marconi site boundary was within ~200 yards of the Chwarel Fawr slate quarry at its closest point). The meeting – unsurprisingly, given the presence and interests of Greaves – decided to form and send a deputation to make their point about the slate industry to the government.

Whilst in 2022, Russia has become something of a rogue state, at the time the Marconi north Wales stations were being completed, it was our ally. During Marconi's visits around completion of the stations, *Yr Herald Cymraeg* (12/5/1914, p.5) reported that he had been joined by no fewer than sixteen Russian scientists. The report also commented how, on some evenings, "flashes" could be seen along the wires. Such flashes were probably the result of wind moving the antenna wires upwards to some degree, changing the capacity to ground on a short (relative to wavelength) antenna with, accordingly, high voltages present and causing support insulators to flash over. This phenomenon is recounted as occurring at Bolinas, California in *The Alexanderson 200kW High-Frequency Alternator Transmitters*, Thorn L. Mayes, Ports O' Call, Society of Wireless Pioneers, 1975, Vol. 4, Appendix D.16.

Workplace accidents were, inevitably, a feature of the north Wales Marconi sites. The death of John Pierce Jones of Portdinorwic, who fell from height whilst erecting one of the 1923 extension masts, has already been mentioned (p.72).

The *Shields Daily Gazette* of 5th of January, 1921 (p.5) reported on a Caernarfon inquest having recently returned a verdict of "Death from shock" on Hugh Roberts, an employee at the Carnarvon Marconi station. The inquest heard how "the deceased was on night duty and appeared to have entered a part of the [transmitter] works where he had no business. There were live wires in the place where he was found dead and employees were forbidden to go there".

Injuries sufficiently serious to be reported in the local press also occurred from time to time.

Evan Jones, of Ty Mawr, Waenfawr, sustained a serious head injury when "moving some of the heavy machinery" – presumably the transmitter hall equipment – during station construction in late January, 1914 (*Y Dinesydd Cymreig*, 28/1/1914, p.5).

William Humphreys, of Bryn Glas, also sustained a serious head injury on Tuesday, 19th of October, 1915, with Griffith Owens, Cae Steel (Waenfawr) also sustaining a light leg injury, when part of a ceiling collapsed on the men during what was described as work "lifting gravel"; the exact circumstances are obscure (*Y Genedl*, 26/10/1915, p.8).

On 6th April, 1915, *Y Genedl* reported that a certain Mr. Barrington – this surely must have been R. N. Barrington, later to become Engineer in Chief at the station – of Pen Greuor (Llanrug), had come into contact with electricity whilst connecting wires on Good Friday, causing what the paper believed could develop into a serious "electric shock" injury.

The Towyn station played its, very early part in gender equality in the workplace, albeit forced by the severe lack of men due to the war.

A whole team of women was trained at a specially-convened (presumably single-sex) Marconi school, opened in February 1916, then immediately disbanded upon course completion, on 30th September. The women were then skilled wireless operators, trained in "slip reading, punching [tape for Morse transmissions], record reading [probably decoding Morse at a human-readable speed, from messages recorded on wax cylinders at high speed], sending on long land lines, and the general duties relating to a wireless station". Anyone who has tried to learn Morse code will understand quite what an achievement this was. It is not known whether these ladies were locals or from afar, or a mix of both.

S2. *The team of lady "pioneer" operators, from a photograph appearing in* The Wireless World*, December 1916, p.677. Back row, from left: Miss W.F. Bruton (who subsequently dropped out of the team), Miss A.V. Edgar, D.M. Jarred, F.M. Rogers. Bottom row, from left: Miss. E.A. Pugh, Miss. M. Beresford, Miss. R. Perry, Miss. G.A. March and Miss M. Murphy. The short article about the ladies' training noted that they were all obliged to work both day and night shifts.*

The weather played its own part in the drama of Marconi stations. The winter of 1914-15 produced a long series of deep low pressure systems rolling off the Atlantic. Carnarvon and, to only a slightly lesser extent, Towyn were both located on extremely exposed hillsides facing directly into the oncoming tempests.

Y Genedl, on the 8th of December, 1914, reported how a violent storm had caused damage to the Carnarvon station, though operations were said to have been unaffected. Capel Croes y Waen's roof was blown off at neighbouring Waenfawr. The NOAA synoptic charts allow us to fairly confidently assess that a low of 970hPa (millibars, as was then used) that swept over the UK on 2nd and 3rd of December was responsible.

There was little respite. By 9th February, 1915, *Y Genedl* again reported damage to the Marconi station, this time amounting to some £300 (around £29,600 at 2021 prices). The NOAA synoptic charts show three deep lows in the north Atlantic at the time, with a 970hPa low around 5th of February likely to have been responsible for the damage.

The presence of the Carnarvon station, together with the comings and goings of its many workers and visitors, became a positive property marketing feature in more than one newspaper advertisement in local newspapers. For example, the *Westminster Gazette* of 8th June, 1926, featured a substantial nearby house for sale in its 'Property Bureau' section on the front page thus:

> Waenfawr, North Wales.—Nine-roomed Freehold house; vacant possession; beautiful scenery, overlooking Menai Straits [sic]; close Wireless Marconi Station; every convenience; ideal summer residence; stand 900ft. Above sea level.—For price and particulars, apply John R. Jones, Arvon House, Waenfawr, Carnarvon.

Finally, at the end of a text far longer, more detailed and wide-ranging than ever anticipated, no account would be complete without some fine Welsh poetry that included the Marconi stations, as notable and dramatic changes to the local landscape of the time.

A short piece, commenting on how surprised and amazed the ancestors would be on seeing the changes to Towyn, was published in the regular section, 'Towyn-on-Sea' – a tongue-in-cheek nod to the anglicised nature of the area – of the November 1913 edition of *Y Llan* (p.7):

Bobl bach pe'r adgyfodwch,
A dadebru fel petae,
Synech lawer a rhyfeddech
Weled Towyn fel y mae

A lengthier, darker and powerful piece – 'Chwefror' ('February') – prompted by a harsh and worsening winter of damaging storms – appeared in the 11th March, 1914 edition of *Y Dinesydd Cymreig* (p.2.), including a line depicting how Marconi's 'iron pinnacles' groaned in the wind:

Chwefror

Aeth Ionawr dros gagendor
I fynwent y misoedd fu;
A ganwyd ei chwaer ef, Chwefror,
O lwyna'r dyfodol du;
Disgwyliem yn gryf ein gobaith,
Na byddai yn blentyn blin—
Y rhodiaf yn awr ac eilwaith
I'n daiar, amgenach hin.

Druan ohonom fe'n siomwyd
Yn waeth—waeth y daeth y drwg,
Dangosodd y bore 'i ganwyd
'Stormus gymylau ei gwg;
Ei hanadl chwanegodd gyni—
Caledi y byd a'i boen;
Haiarn binaclau Marconi
Ruddfanent gan wynt ei ffroen.

Y derw fu'n herio 'stormydd
Am oesau heb grymu bron,
A blygent fel brwyn yn ufudd
Ar ddydd genedigaeth hon;
Ca'dd tô llawer bwthyn bregus
Ymuno a thô y plas,
I chwifio fel adar chwareus,
Fry, fry yn yr awyr las.

O! Chwefror! Dy chwerw wyntoedd
Ddiffoddodd obeithion hedd;
Y morwyr, drwy'th lid, a gwympodd
Hyd waelod hallt eigion fedd
Gostega dy dymestl greulon
Am enyd i glywed cri
Y mamau, y plant, a'r gweddwon
Alarant o'th blegid di.

Breuddwydiem dy weled, Chwefror,
Yn tramwy yn ddistaw bach,
Tan wenu yn gu i agor
Y drws i'r tlws Wanwyn iach;
Troa dy gefn ar y Gaeaf,
A gwawdia ei feiddiol her,
Edrych at Haf a Chynhaeaf,
A brysia—mae'th oes mor fer.

Dy wynt, dy rew, a'th eira,
Dy wlaw, a'th d'ranau di-hedd,
Yn gymhleth a'th haul gyfoda
Dwf-fywyd y byd o'i fedd;
Fe'n dygi i fywyd gwynach—
Hinion y Gwanwyn a Ha';
Ni chofiwn dy chwerwedd mwyach,
Ond cofiwn dy bopeth da.

W. Gwynant Humphreys.
Llanrug.

A short piece, written specifically about one of the Marconi stations – perhaps Carnarvon, but it is not altogether clear – appeared in a Welsh section of the otherwise English language, *The Cambria Daily Leader* of August 8th, 1916 (p.2), the author being resident a long way from either station, in Carmarthenshire.

Y Marconi

Gwib ehedeg heb aden – wna'r pellebr,
Heb ball, lwybrau'r fellten;
A geiriau byw geir o'i ben
Heb gyfrwng undeb gwifren.

D.J. Howell, Llanymddyfri.

Y Genedl of 28th August, 1917, published a work about the environs of Isaled by 'Penllyn', which includes the Carnarvon Marconi station, described as carefully listening for messages (in fact Carnarvon only transmitted, though it could be configured for receiving) by means of its 'second-sight' abilities. It may have been written during a period of home leave during the war.

YN YR ERW

HEN GARTREF ISALED

Yn yr Erw 'r wy' i aros—mewn llwyn,
Man llonydd, bythefnos;
Byd a'i niwl enbyd, a'i nos,
A'i wg, na ddoedi yn agos.

Os yw hwyliau Isaled—yn aros
Mewn Erw ddedwydded
Drwy y clai medra'u clywed
O'r glyn, yn ei Erw gled.

Swn y frân sy' yn y fro—lawer
Dylluan yn cwyno;
Heb achos—teirw'n beichio,
Bref faith a llywaith y llo.

Yn ei swydd mae anfon Saint—yn pesgi
Pysgod ei llifeiriaint;
O dwyn a moel daw'n ei maint
Yn lan fel nefol enaint.

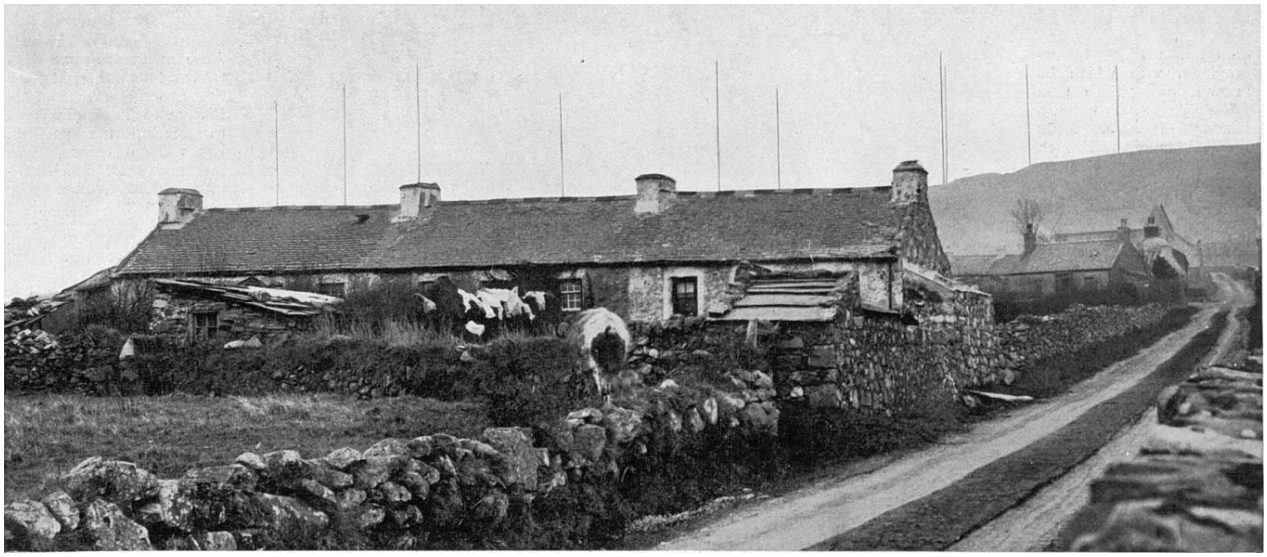
Ym mrig Ceunant, Marconi—a fanwl
Glustfeinia o ddifri;
Erys am genadwri
Drwy eu ddawn ail edrydd hi.

Ar yr hardd Eryri wen—dra uchel,
Edrychaf yn llawen;
Yn ei thlysni phwys ar ei phen.

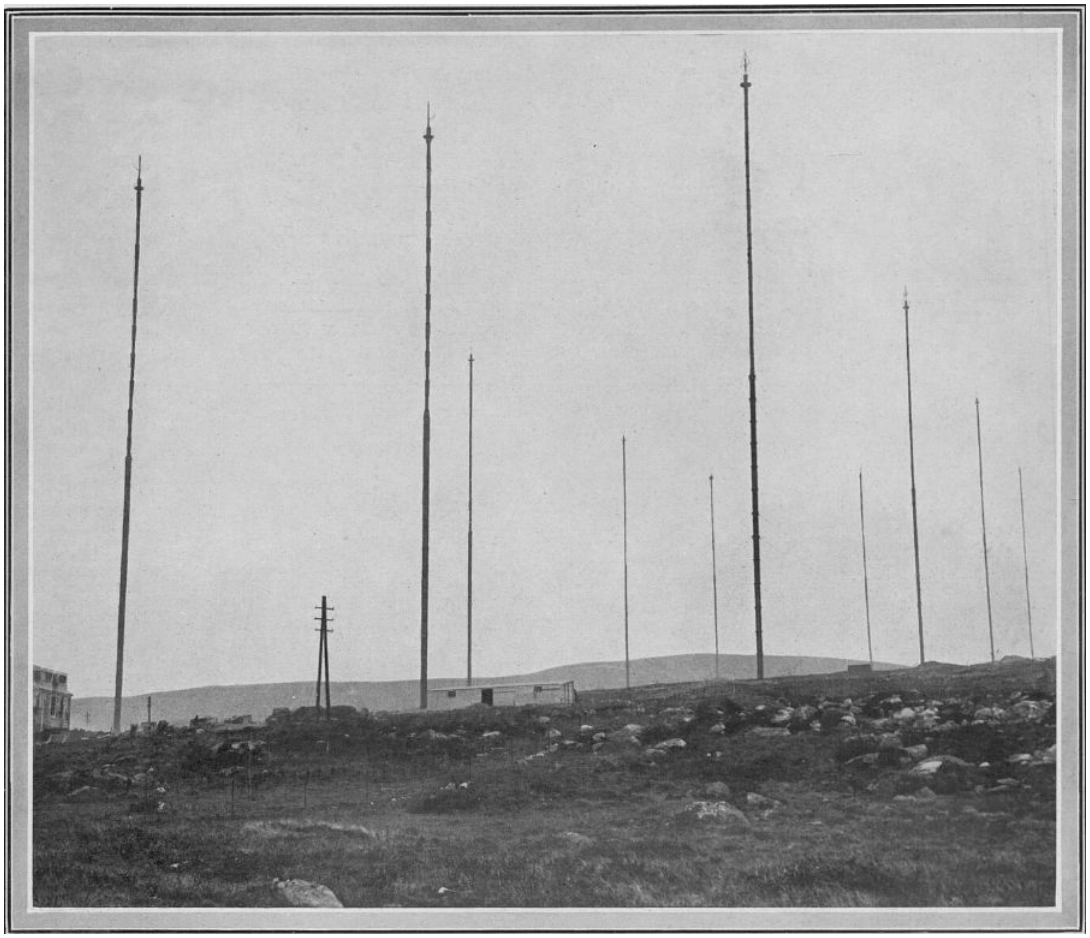
PENLLYN.

2023 -2024 follow-up work.

The following images came to light during 2023, following the conclusion of the first edition of this text:



D1. *The entire span of the 1914 antenna, seen from near the junction at Groeslon, on the hill leading up to Cefn Du (approx. 53.117233, -04.201832).* The Sphere, *10/1/1914, p.39.*



D2. *The entire 1914 antenna, from the lower SW of the site, seemingly before radiating wire installation. Note the AC supply pylon from Cwm Dyli.* The Sphere, *10/1/1914, p.39.*

Early 2023 work focused on surface vegetation clearance at the double ATI house. The aim was to both uncover detail of the drainage arrangements and any new ceramic remains and to improve drainage to reduce the damaging effects of long-term freeze-thaw action upon the concrete base; the covered areas of the base were found to be in significantly worse condition than the exposed.

The 'French' drain that still runs, largely uncovered by vegetation, forward of the 1914 antenna-facing gable, is now understood to have surrounded the double ATI house. Located within an excavated platform the site was then immediately prone to surface water run-off from the higher ground towards the 1923 extension. Water runs over the site even under lengthy dry weather periods in summer; efficient drainage using loosely-packed stone drains was therefore essential. The drainage area facing the 1914 antenna remains unclogged, a century after its construction, and still removes water quickly.

The approach to the double ATI house porch was also cleared of vegetation and cleaned back to the surface as it was when the station was in operation. A few new patterns of ceramic remains were found, including 4½" OD torus bases that were retainers for the feet of pillar insulators at the base of the ATI inductors.

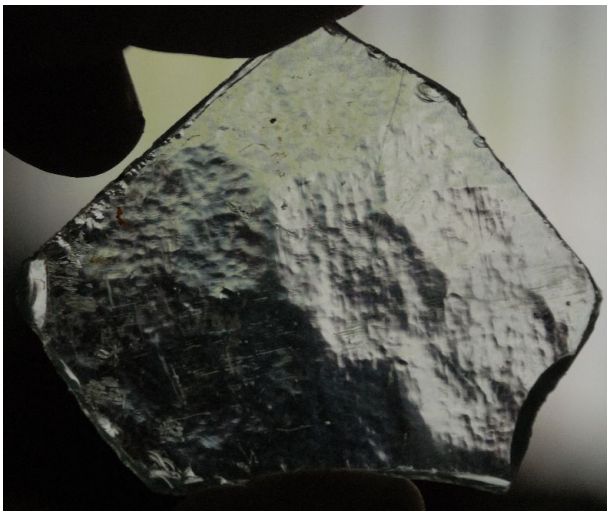
The approach to the porch itself consisted of fine grit which, towards the south, was markedly higher than the concrete ATU base and therefore unlikely to have been a drainage route. Clearance of the moss and heather to the south of the ATI base confirmed that the internal drainage from the double ATI, previously shown to empty at the SW corner of the porch, made its way into the 'French' drain running SE-NW along the southern edge of the double ATI. A not-insignificant drainage today occurs – and may well have occurred in the past – from the eastern end of the platform, under the concrete base, which is only some 20cm thick.

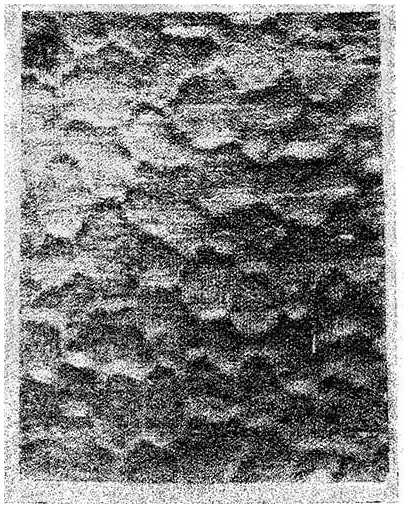
The schematic of the double ATI at **71** has been updated for this edition in order to show new understanding. This includes slight adjustment to one of the concrete measurements after removal of overlying vegetation that had earlier made accurate measurement by trial holes somewhat difficult.

D3, *left: the turn in the double ATI at the north-eastern, 1923 array-facing elevation, evident from the run of the internal drainage channel. The removal of this strip of overlying bog required some six hours' careful removal by small spade.*

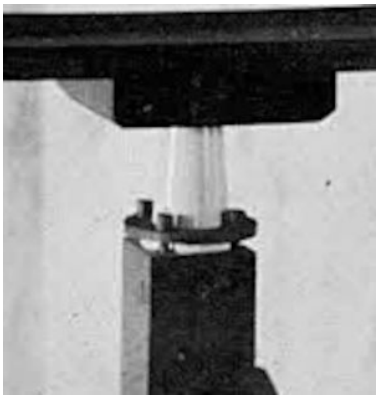
D4, *below: small lead fragment found during the clearing work at the double ATI, retaining white paint covering, probably from an external window sill flashing.*

Small glass fragments, representing remains of the double ATI's windows, were recovered adjacent to their originally-installed positions. As noted in the main text and is indeed evident from close examination of the photograph at **72**, the window glass was of obscuring, patterned design that prevented prying eyes from seeing the detail within. The warning sign of high voltage (see **73a**) seem as much aimed at workers as any curious members of the public that might have been expected to drift by from time to time, notably when the site was no longer protected by the military as it had been during WW1.





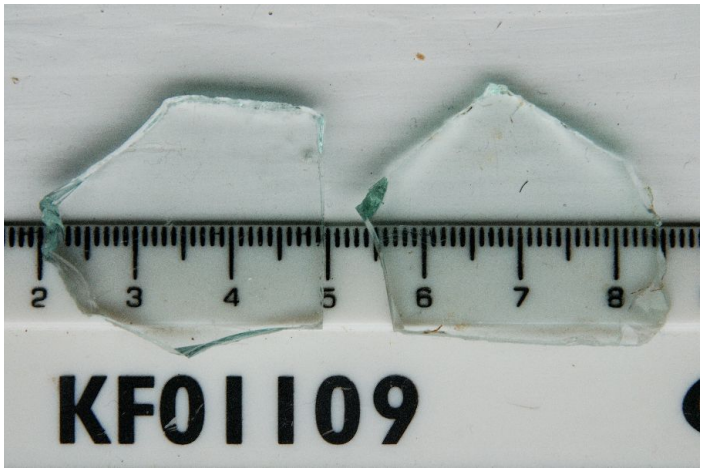
D5, *left: roll-patterned glass from the westernmost window of the southern elevation of the double ATI, tentatively identified as Chance Brothers (Glasgow) Scintilla' Cathedral design, produced between 1911 and 1925 (the double ATI being installed in 1923). Right-hand image is a poor brochure-type sample photo, as presented by Sashwindowspecialist.com blog ('Old Window Glass: History of Textured and Patterned Sheet Glass). Similar or identical glass was also used to partition Towyn receiving desks.*



D6*: Found outside the porch door area of the double ATI, partial ceramic ring with four bolt holes (upper right fragment is from a different whole), proved to be retainers for inductor base pillar insulators, seen in MS.Photogr.c.243, image 747/x (see* **78** *for entire photo).*

D7, *left: found near the angled turn at the northern end of the double ATI, a ceramic, single-piece threaded bolt. The inductor ring above is seen to have such a handle on its bolts, but it is not entirely clear if they are exactly the same type.*

D8, *right: fragments of clear glass (3mm thickness) found with others in front of the porch door and almost certainly once part of that door's glazing, which is seen to be clear in photo* **73**. *Scale in cm/mm.*



D9, *left: (from left) – iron drainpipe fragment (2 ½" OD, 2" ID) from the NE corner of the double ATI, together with (also at same location) red unglazed ceramic slotted inductor pillars (see* **C7***), white glazed ceramic rod insulator fragment, with a disc insulator fragment to its immediate right, a white glazed capacitor bridging insulator (top right) and several early thermoplastic insulators, possibly gutta percha, of uncertain function, but probably inductor-related, at far centre right. Tape open to 1ft.*

D10, *right: found at the double ATI, though almost unrecognisable due to 84 years' rusting in the acid, wet ground, these small fragments are of corrugated steel sheet which can be taken to be confirmation that, as for the single ATI, the double ATI outer skin was of this material. Curved steel washers found nearby also add weight to this conclusion. Asbestos internal lining was also found in abundance near the feedline entrance point and other locations around the double ATI house.*

D11, *left: fragment of cylindrical/rod glass insulator, precise function unknown. 24mm OD.*

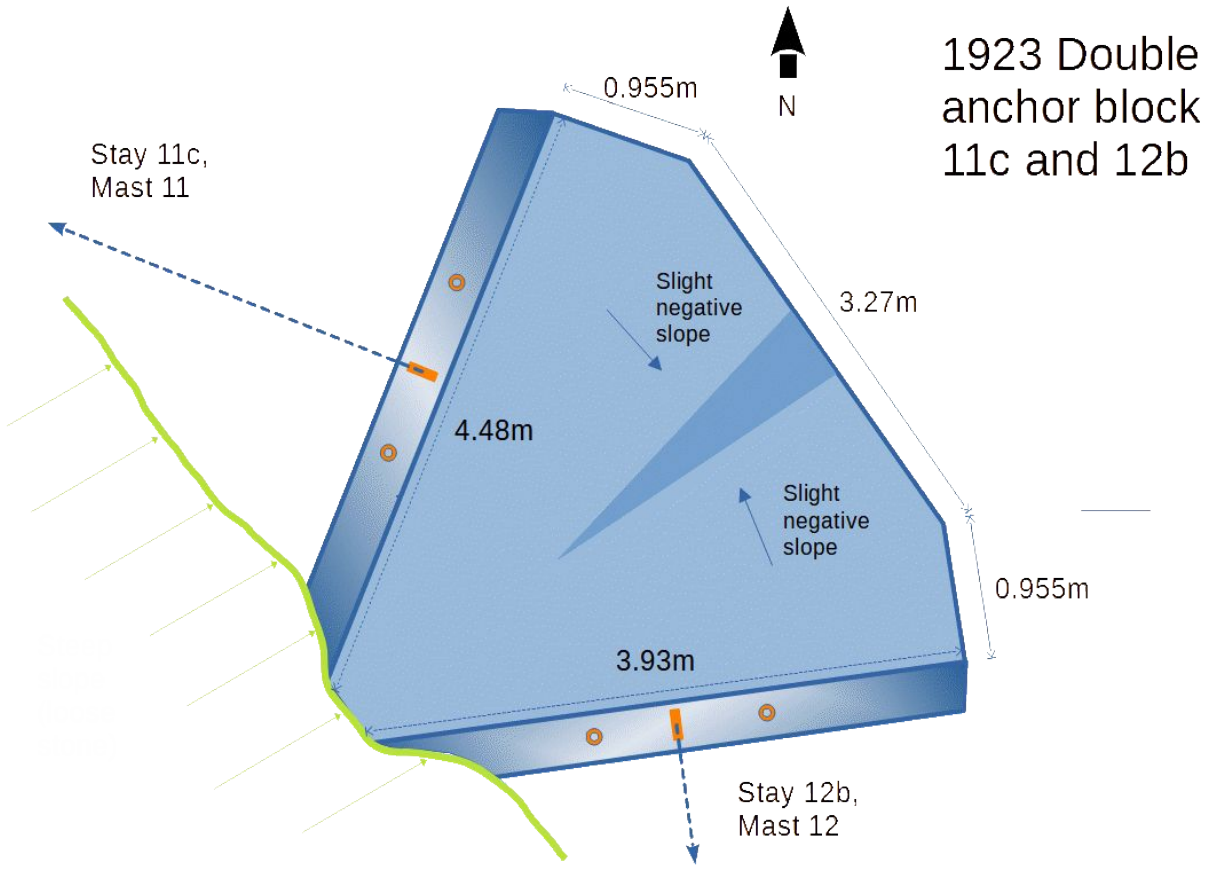
The 2022 discovery of a remnant stranded copper wire (see **53**) at the base of a 1923 support mast (of unknown purpose as it was offset from the pattern of counterpoise supports), delving into broken stone ground proved to be too time-consuming then to excavate carefully. By April 2023, the weather was such, and the workload enormously less, that a morning was given over to pursuing the cable's path in the ground. The cable was fairly quickly found to run and be firmly attached to a vertically-emplaced galvanised steel sheet of ~2mm thickness. The sheet appears to surround the concrete base. The arrangement appears to have simply provided grounding of the mast itself. Another example of 1923 base, also lying outside the counterpoise support pattern, has the steel sheet much more intimately associated with the concrete, and has the appearance of having lined the hole into which concrete was later poured.

D12, *left: 1923 support mast concrete base, with location of copper wire attached to surrounding galvanized steel plate, below scale arrow. The mast was offset from the pattern of counterpoise supports, and there are two other known examples. Their purpose is not yet known.*

D13, *below: detail of wire connection to plate, the upper plate edge highlighted in yellow line. Tape open to 1ft, north indicator scale in cm squares.*

A closer examination of the upper, 1923 double guy anchor was undertaken in response to an extremely poor description for its entry in the official historical environment record (National Primary Record Number (NPRN) 505603) and the author's wish to substantially improve that record in general.

Whilst the function and overall form of the anchor was well-understood in 2022, full measurements and an examination of its immediate surroundings – often known to reveal ceramic and other remains – had not been done. This work was completed in mid-April, 2023.



D14*: 1923 upper double guy anchor base, not to scale. The elevations facing the antennas are sloped, as loosely indicated by the shaded fill. The orange circles indicate (now cut) steel loops, probably for construction or erection guying, and the orange rectangle indicates the main guying attachment point for the turnbuckle (see* **138***). Green indicates steeply sloping ground to the SW.*

Simply removing surface coverings of moss and heather revealed that several tubular ceramic insulators with two ribs lay at the southern base of the block. These had been broken upon liberation from their metal housings by salvagers in 1939, but gave the best indication of dimension and form yet found for this type of insulator.

Accurate dimensions could now be taken. It was also revealed that the south-western 'point' of the block runs up against the rock of steeply-sloping ground (green in schematic) and, as a consequence, has been concreted up to and includes some of that rock, rather than having a constructed elevation at that location.

D15, *left: 1923 upper double anchor block following moss/heather removal, looking east. The flat area in the middle distance is the trackway area seen in* **139**.

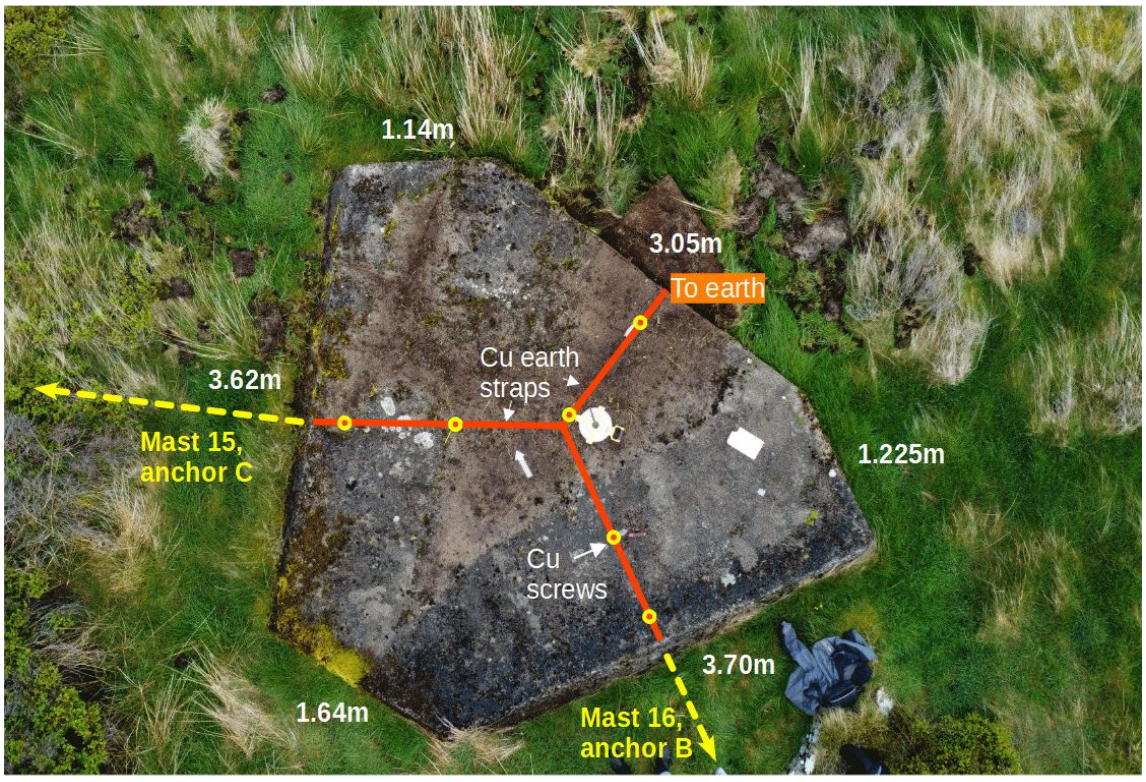
D16, *right: tubular insulators once making the link between anchor block and guy wire* via *metal retaining fixings – see* **50**. *Located at base of southern, mast 12 -facing, sloping edge of 1923 upper double guy anchor.*

D17, *left: tubular anchor wire insulators and disc 'reel' insulator remains. None bear a maker's mark. Tape open to 1ft, trowel blade = 6". 1923 upper double guy anchor.*

The acquisition of a small camera drone during early 2023 allowed general and, of particular benefit, vertical images of the more significant features at the station. This included the upper and lower double anchor mast bases.

D18, left: aerial view of upper double anchor base for mast 11C (to upper left), 12B (to lower centre right). Dimensions as given in D14.

D19, below: aerial view of lower double anchor mast base for mast 15C, 16B. The earthing arrangements were the same for the upper double anchor and all guy wire anchors had such earthing, ultimately terminating in a glavanized sheet inserted vertically into the ground a short distance from the anchor.



Every year, on April 22nd, the Dragon Amateur Radio Club operates a small high-frequency station from upstairs within the Carnarvon transmitter house. The 2023 event afforded another opportunity to take some notes and photos of the interior, now serving as horse stables and remaining in reasonable condition.

D20, *left: Interior vitreous glazed brick arches at the eastern, antenna-facing side of the transmitter hall. The arch infills are modern and now form part of a horse stable. The roof truss timbers are original and currently in excellent condition, though roof damage now threatens the long-term integrity of the building in general.*

D21, *right: the same arches as in D18, but taken from near the windows at the eastern elevation of the transmitter hall.*

D22, *left: the northern side of the eastern elevation of the transmitter hall, facing the antenna. Note again the currently excellent condition of the original roof trusses. The flooring remains original, though the concrete machine bases have been removed entirely.*

D23: *Dragon Amateur Radio Club members (from left) Danny Shurmer GW7BZR, Simon Taylor MW0NWM and Tom Hughes 2W0IJD, during International Marconi Day, April 22, 2023, operating from upstairs within the transmitter hall at Carnarvon on the 7MHz band.*

Immediately outside the steps leading to the first floor of the transmitter house lies a 6ft square concrete base with substantial, 1¾” bolts at the corners. This had previously somehow escaped the author’s attention, but is instantly recognised as the base for one of two half-sectional steel tube masts located either side of the transmitter house. These suspended a catenary over the building that strained the radiator wires to a common anchor to the west, near the accommodation block (see **56**).

D24, *right: concrete base (foreground) with embedded vertical bolts, the base for an earth catenary tubular steel mast support. The power house building, now a domestic dwelling, is seen in the background and, in 2023, was externally clad in timber. Due to such modifications, the power house has failed to meet listing criteria and cannot be protected by law – another tragedy of long-term laxity within the Welsh heritage agencies.*

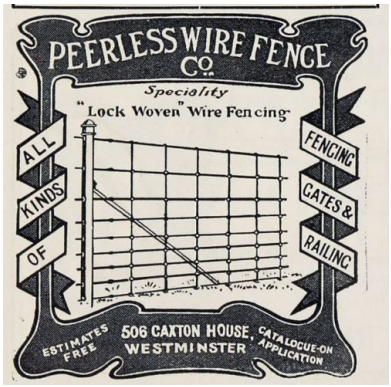
The access way uphill from Ceunant Road to the station also revealed new detail, escaping attention in numerous past visits.

Two gates, now integrated into a rudimentary modern wire fence, stand open, still attached to decorative iron pillars, still in very good condition, bearing the raised letters (running vertically, as installed): ‘Peerless Wire Fence Cº’ and, underneath, ‘Caxton House Westminster’. *Grace’s Guide to British and Industrial History* includes an entry for the company, with two example newspaper adverts, but not further detail. One of the adverts (see below) is given as being from 1913.

D25, *left: accessway gate, one of two that seemingly overlapped, and ornate iron gatepost by Peerless Wire Fence Cº.*

D26, *below: turned through 90 degrees to render it more easily readable, the raised lettering of the company name and location.*

D27, *right: 1913 newspaper advert for the Peerless Wire Fence Cº., presented by* Grace’s Guide. *Other examples are present in the general newspaper archive around this time.*



Attention then turned to what I described – very much in passing during the heavy workload days of 2022 – as an ‘incline landing stage’. This was a small concrete platform, much overgrown, that did not appear to have any embedded bolt remains for the attachment of machinery, as found on all other similar bases around the site. It clearly lies at the head of an incline running up the antenna field from the west north-west, but also appears to be a focus for trackways leading to it from the north and the south.

Removal of surface vegetation was conducted in late April 2023. The concrete platform was revealed to measure 2.5m by 1.42m, with the easternmost (short) edge being obviously curved for the last 15cm. This curved face was found to have severely decayed but still recognisably – by visual examination and, particularly, touch – corrugated steel sheet in intimate contact, possibly as a former; it’s use as siding is considered unlikely, given it seems to curve with the concrete, but it cannot be ruled out.

At the northeastern corner, an oval metal fragment, a band of metal 2¾” wide and apparently containing rivet heads, was found just beneath the overgrowth. Badly decomposed in the acid soil, it was nevertheless recovered without damage. The internal oval diameter was 1ft. It is unclear whether or not it was originally more circular in shape.

D28. *Concrete platform and lesser platform to its right, separated by a 1ft sloping gap. The second platform seems, from the sequence of concrete at the foundation level, to have been built after the first, main platform. The platforms are at the head and aligned with the centre of an inclined trackway running at least as low down as Mast 9, the centre mast of the rearmost three masts of the original, 1914 antenna. The recovered oval band is seen, placed for documentation, with the tape open to 1ft. The transmitter hall lies in front of the trees in the distance (upper centre).*

A second concrete platform was discovered, separated by a sloping gap of 1ft between it and the main platform. This is seen to be much less well-defined a platform than the other, with its northern side entirely ill-defined in concrete that simply seems to peter-out. Careful removal of peaty overgrowth on the second platform revealed a deposit of small coal and clinker fragments, together with several larger pieces, up to a couple of centimetres across. The coal provided the required insight into this feature of the Marconi site in that it was clearly fuel for a steam boiler. The oval iron band may or may not be distorted, but it was certainly part of the boiler; bands with rivets can

be seen in portable boilers of the time. Further careful excavation by stiff brush revealed part-molten clinker, a characteristic waste product of steam engines.

D29. *Recovered oval iron band of 2¾" width, the oval's long axis internally being 1ft (tape open to 1ft), though it may have originally been more circular shape. The outer perimeter of the band is badly decomposed but contains identifiable rivet heads. This, in tandem with the coal found next to it, very strongly suggests it was part of a steam boiler for powering an incline head winder. If the oval shape was original, it was likely part of the fuelling door assembly.*

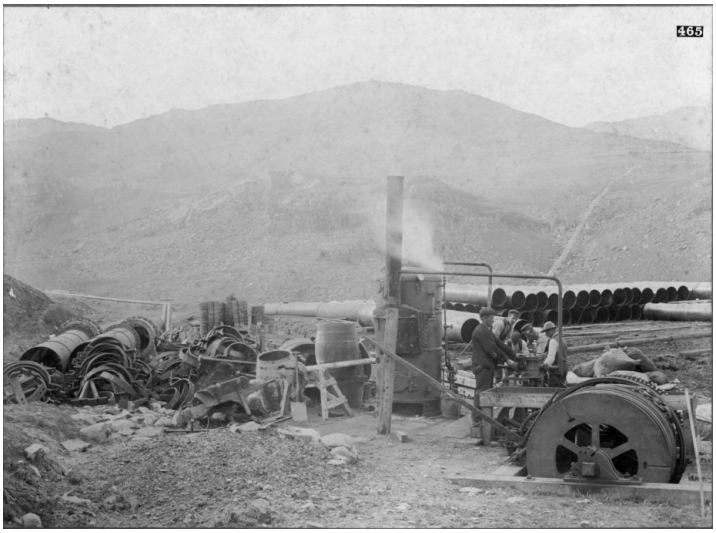
D30, left: c*oal fragments, one showing a characteristic sun glint, found at the centre of the second, poorly-defined concrete platform. Most of the base area is covered in much finer coal fragments. The lack of anchoring bolts for any machinery is likely a result of the temporary nature of the portable boilers and winders. There is no question that this was the location of a steam-powered incline winder, the fuel remains indicating where the boiler once stood.*

D31, right: *part-molten clinker, a tell-tale sign of a steam engine at the incline winder location.*

D32, left: *Main platform base after brush cleaning, showing narrow channel, draining to the rear and light impressions in the concrete surface, potentially those of double-bend pipework. The lime-rich concrete surface appears to be somewhat heat-modified at this point. Orientation as per arrow, 1ft gap between bases at far right, incline direction is to top centre (W-NW).* **D33,** below: *aerial view of winder site.*

These findings crucially provide the first known, direct physical evidence that confirms the early 1910s accounts of steam engine-powered trackway winders having been used at the site. That this material survived on a wet, acid hillside in sufficiently well-preserved condition to allow understanding, 110 years later, is little short of a miracle and a highlight of this whole work.

The question then arises: what kind of steam haulage was it? What did it look like? Thanks to the decades-long experience of slate specialist industrial archaeologist and author, Graham Isherwood, we now have a very good and perhaps definitive picture. Graham passed on a scan, originally a photograph from the Gwynedd Council archives, of just such an engine in use for the construction of the electricity supply line from Cwm Dyli to the Glynrhonwy slate quarries – a line that was shared at one time with the wireless station.



D34: *The steam haulage engines used for constructing the Marconi site were similar, if not identical to the ones used in 1905/6 for the construction of Cwm Dyli's supply pipes and power lines. Graham Isherwood considers that no permanent mounting was required for the haulage loads likely at Carnarvon, with temporary 'pegging' being sufficient to stabilise the system. Note the long brake lever. The engine is of a type widely advertised by Appleby Brothers of Southwark, London as being 'semi-portable', of which this may have been an example. Gwynedd Archives XS1245.6, under academic licence.*

More detail on the 1923-1924 extension array grounding.

The stay cable anchor 13/17A and a nearby counterpoise mast base were examined in early summer 2024 in order to determine if, as mostly overgrown remains, they might reveal any new information on clearing.

It was quickly discovered that a substantial part of the grounding band for the stay cable remained fixed in the ground, with a short length protruding from the rear of anchor block 13/17A, where it had been cut by salvagers at the top surface level.

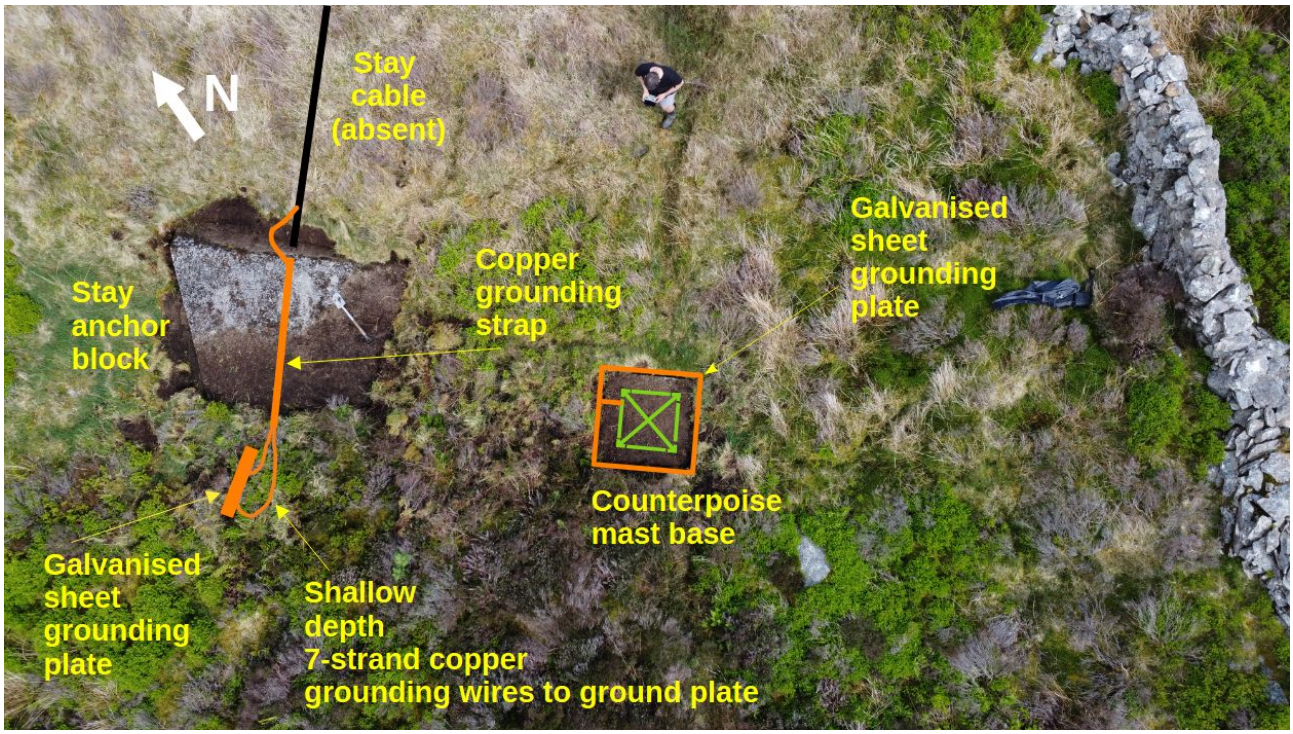
The band was found to be non-magnetic and therefore copper or copper alloy. It measured 22mm wide by 1mm thick, with a remaining length of 95cm overall. The band was buried at shallow depth – approximately 4" – within ballast-sized broken stone. This type of covering appears to have been used across the whole of the Carnarvon site, at least from the time of installing the elevated counterpoise, when counterpoise masts seem to have been connected to one another by copper wires buried along shallow cuts.

At the ground end of the copper band were bonded, by some remarkably durable soldering that remains largely sound, 100 years later, despite having been placed in very acidic, wet ground, two 7-stranded copper wires. These connected to a relatively thin, zinc-plated iron sheet placed vertically in the ground.

Stay cable anchor block 13/17A grounding strap, cut by salvagers at the centre rear of the anchor but with 95cm of the strap remaining in the ground. Scale squares = 1cm, ***not*** *indicating north.*

*Excavated grounding strap (right) for the stay cable of Mast 13/17 at anchor block 13/17A, with two bonded, 7-strand copper wires running into the earth. The wires and band were covered with ballast-type stone. Scale squares = 1cm (**not** arranged to show north).*

Right: detail of two, 7-strand copper wire metallurgically bonded to the copper grounding strap. The bonding remains strong and mostly uncorroded after 100 years in the ground.



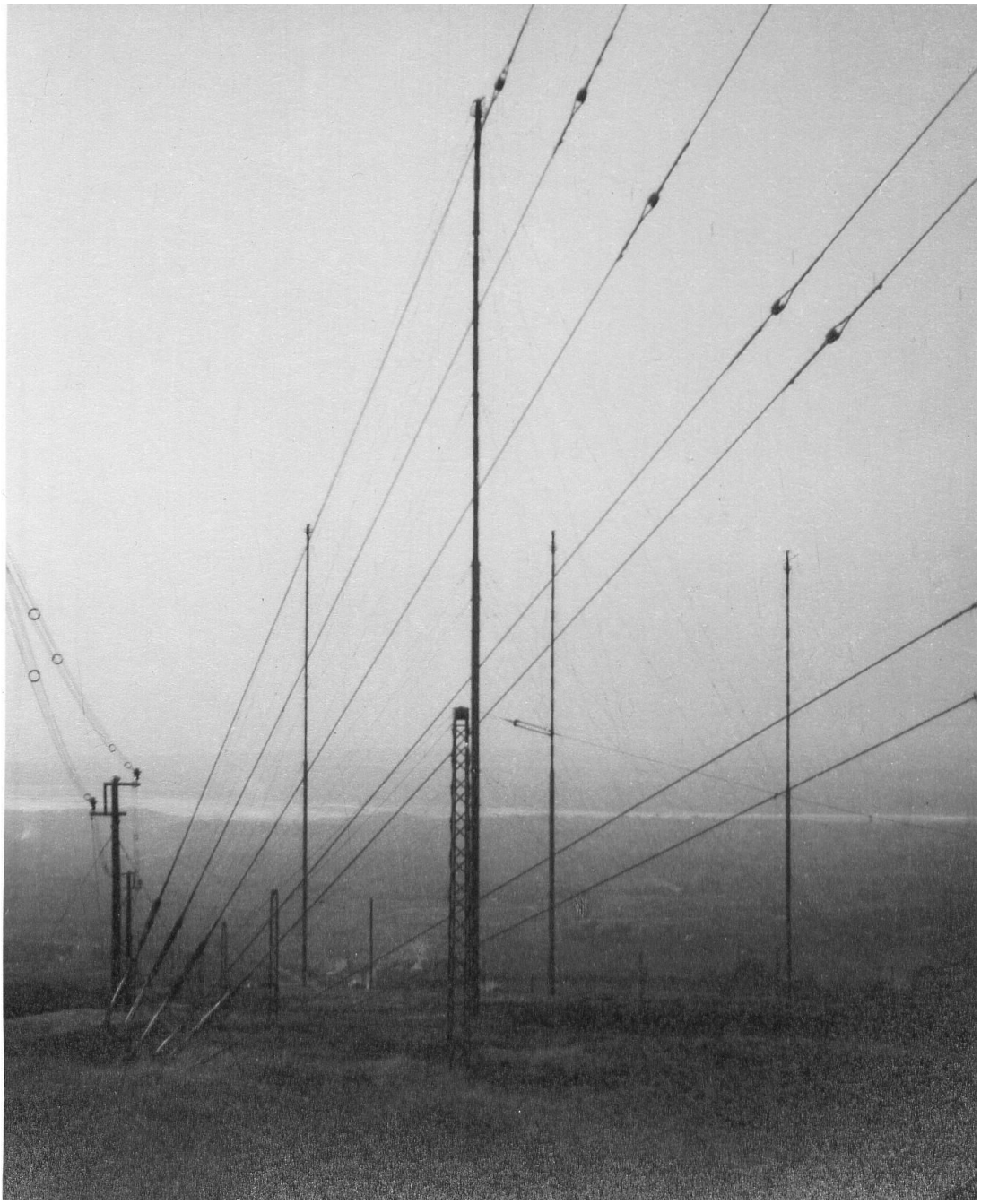
May 2024 drone image of stay anchor block 13/17A at left, with an elevated counterpoise mast base alongside at image centre. The orange lines indicate the grounding arrangements revealed by excavation. For scale, the counterpoise mast concrete base is 4 feet on a side.

Discovery of new photographs!

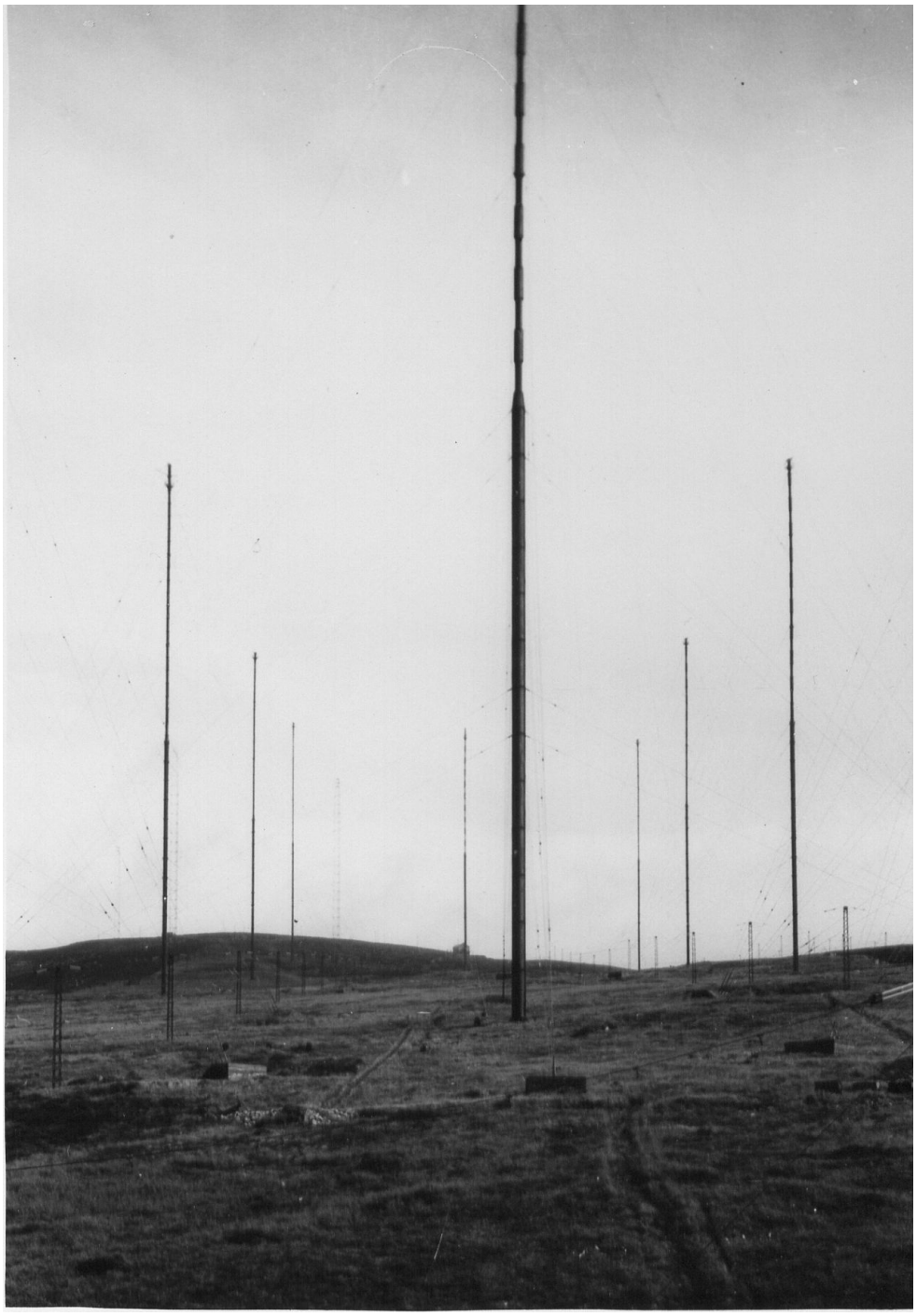
In late summer, 2024, whilst reading the fine 'Point-to-Point' book by Paul M. Hawkins, I came within it a handful of images that I had not found in the Oxford Marconi archives. Curious, I enquired with Paul as to where he had come across the photos. Paul had been offered the collection of material relating to 1920s Engineer-in-Charge at Carnarvon, R.Noel Barrington several years earlier by a widow of a man who worked at Dorchester radio station – where Barrington later ended-up. Paul agreed to accept them, which very probably saved them from being forever lost from the record. Paul kindly and quickly agreed to share good quality scans of the photos with me. I and the wider wireless history community are indebted to him for doing so.

We learn or confirm some important aspects of Carnarvon's layout from the Hawkins' collection. Firstly and for the first time, we can see that the balanced (twin) feedline to the upper, N$^{o.}$2 array was not buried along the ground from the transmitter hall to the double ATI as previously thought. Instead, the caged wire feeders, wires kept apart in each line by hoops and the whole termed in a description of the time as "sausages", were transported up Cefn Du by timber telegraph poles along the southern boundary of the property, each side of the line separated by about 4 feet on the poles. This explains the appearance of many of the telegraph stay buckles that were identified during my fieldwork, the attached cables of which can clearly be seen in the relevant photograph. The text document that recounts the detail is not indexed, but seems to be a recollection by a former worker at Carnarvon, a part of the Cable and Wireless archive currently held by the Porthcurno museum of international communications (once, site of the cable station, callsign 'PK'). The feedline was connected to 'Poldhu pots' at intervals, these being loading condensers. The arrangement was

problematic due to high voltages and consequent flashovers, requiring men to very regularly carry heavy replacement condensers weighing some 4cwt (about 200kg) up the hill. The account claims this use of balanced line may have been the first implementation of this, then poorly understood, feed system.



N1. *A very important photograph of the MUU array, dating to around 1925, showing detail not previously known. The elevated earth screen mast, insulators and wire is seen more clearly in this image than any other by far. Also of critical importance is the appearance of the telegraph poles carrying what was in effect a balanced feedline of caged design up the southern boundary of the site. Such feedlines were not well understood at the time and Carnarvon is believed to have been instrumental in their experimental deployment. Also seen reasonably well for the first time is the triatic suspension system leading north from the nearest mast (mast 5) Image courtesy of Paul M. Hawkins.*



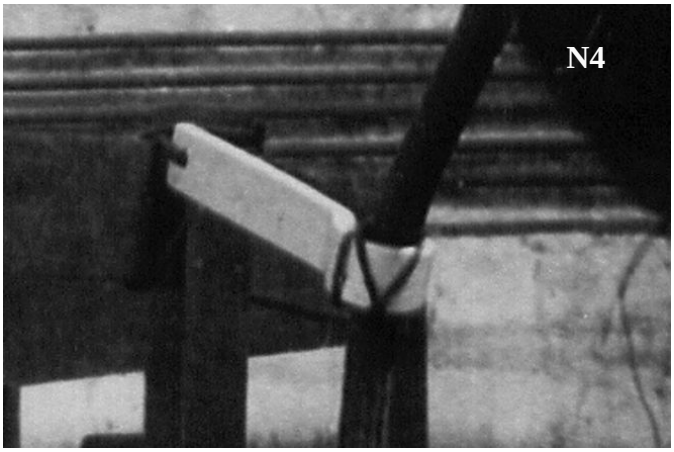
N2. *A rare and relatively clear view of both the 1914 and 1924 array, together with part of the elevated counterpoise system, captured in this ca. 1925 photo taken by R.N. Barrington. The double ATI is seen on the hill, just to the left and behind the rear centre mast (mast 9). This and another photo clearly shows side arms emerging to the north of the 1914 masts 1 and 4, but not from the corresponding southern outer masts. These could either have been triatic lowering and raising-related, or else may be structures from which GLJ was slung. It is not currently clear which of these possible roles is correct.*

N3.

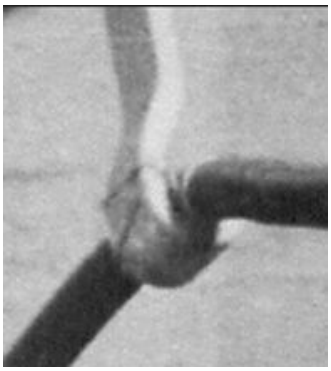
N3, *above: a very clear 1924 image of the lead-out variometer at the transmitter hall. With enhancement, the ammeter appears to indicate about 150A. The radiator feed passes through a glass insulator window. The variometer has a graduated scale. A small part of the feeds appearing across the window were apparently contemporaneously hand-retouched.*

N4, *right: holed and hooked porcelain insulator supporting a ground feed wire that is strapped to it. The wire connects to the two insulators for the ground connections either side and below the window (one directly above the ammeter).*

N5, *right: the same type of ceramic cable retainer seen at extreme upper right of the photo.*



N4

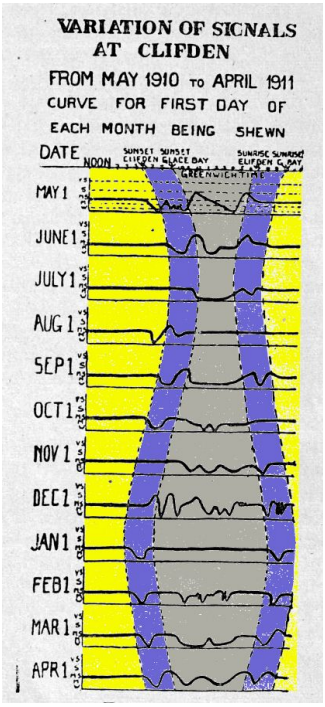


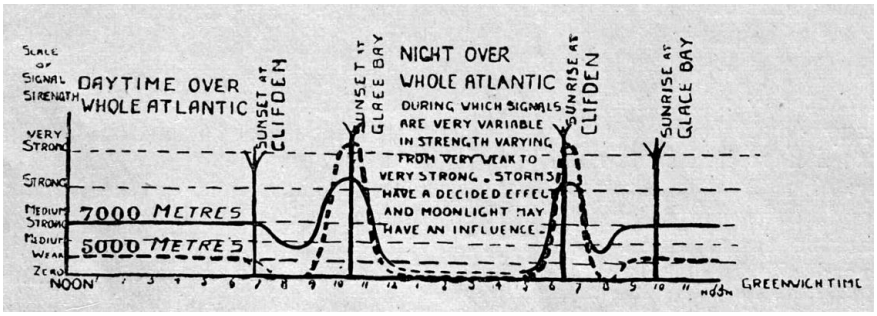
N5

Propagation at VLF.

One topic not covered in the earlier editions was what VLF propagation over the course of a day and throughout the year looked liked.

Luckily, plots of the Glace Bay signal heard at Clifden were made at the time and presented to the Select Committee on the Marconi system.





D35, *above: originally diagram 3 in Marconi's evidence to the Select Committee (op.cit., p.5), the diurnal variation in Glace Bay signals heard at Clifden. Note the belief in a potential effect from moonlight, probably intended to mean the lunar cycle.*

D36, *left: originally diagram 4 in Marconi's evidence to the Select Committee (op.cit., p.5) and coloured for the present text to afford easier interpretation, the variation of signals from Glace Bay heard at Clifden on the 1st of each month across the year. Yellow = daylight; blue = twilight; grey = darkness.*

The following extract from Marconi's submission to the Committee (page 5-6) describes the changes in propagation:

> "Although as a rule messages can be sent at all times of day and night between Clifden and Glace Bay, there still exist periods of fairly regular daily occurrence during which the strength of the received signals is at a minimum. Thus in the morning and in the evening, when, in consequence of the difference of longitude, daylight or darkness extends only part of the way across the ocean, the received signals are at their weakest. These variations seem to be less in a north-southerly direction than in an east-westerly one. I have some diagrams which have been carefully prepared, which show the average daily variations of the signals received at Clifden from Glace Bay. These diagrams I produce, and, should the Committee at any time desire it, I should be glad to explain them.
>
> The strength of the received waves remains as a rule steady during daytime. Shortly after sunset at Clifden they become gradually weaker. About two hours later they are at their weakest. They then begin to strengthen again, and reach a high maximum at about the time of sunset at Glace Bay. Then they gradually return to about normal strength, but are variable throughout the night. Shortly

before sunrise at Clifden the signals begin to strengthen steadily, and reach another high maximum shortly after sunrise at Clifden. The received energy then steadily decreases again until it reaches a very marked minimum a short time before sunrise at Glace Bay. After that the signals gradually come back to normal strength.

Diagram 4, which I also produce, shows the curves for the first day of each month for one year from May, 1910, to April, 1911. I have already shown these diagrams in a lecture I have before the Royal Institution on June 2, 1911, and I also showed similar diagrams in a paper read before the New York Electrical Society on April 17, 1912. I should explain that the ease of communication and readability is, of course, at its maximum when the lines are furthest from the zero mark. When the lines are very near the zero mark the signals are either unreadable or readable with difficulty. It is perfectly true that there are periods which occur occasionally, of two or three hours' duration, sometimes during which communication is difficult and sometimes even interrupted, but this is now of rare occurrence.

This is caused by reason of insufficient effective power available at the Clifden and Glace Bay stations, and satisfies me that my original calculations that to effectively penetrate the medium at all periods during all seasons 300kw. [sic] of effective power was needed."

The Military Blockhouses.

The sheer scale of work required at the site during 2022 was such that detailed attention to most of the blockhouses, the majority of which are now entirely ruined, could not be given. Work in the early summer of 2023 aimed to correct this. All images are either summer 2022 or early 2023.

Blockhouse 1 is located at the approach to the station, very close to the engineers' accommodation of Marconi Hall. As previously noted, nothing much of this now exists, other than its potential general outline and part of the western and southern elevations. It appears to have had dimensions of approximately 34 feet long by 20 feet wide (10.3m by 6.1m), though it is possible the modern outline is not an accurate reflection of the original construction.

Blockhouse 2 is the first blockhouse out amongst the antenna field. It is at the lower end of a long inclined trackway bed that runs to the summit of Cefn Du. Together with blockhouse 5, it remains the only blockhouse where much of the structure remains intact, though the western and northern elevations have whole-height wall failures due to subsidence of the simple stone foundations, which incorporate a slate damp proof course, on boggy ground. The firing 'ring' of shooting holes number 6 on the southern elevation and 8 on all other elevations. Each firing position, as in the case of all other blockhouses, has a fluted shape with a slate upper face, narrowing to an aperture of 11.5cm wide by 20cm high as a 'standard' size at the external face of each elevation. On the eastern elevation, which faced uphill, the apertures have been made taller, typically measuring 32cm high, to allow the necessary above-horizontal firing uphill – though there is no record of the station being attacked.

Left: blockhouse 2, southern elevation, with remnant porch, in front of doorway, western elevation to the right.

Blockhouse 3 is the next blockhouse along the inclined trackway leading to the summit of Cefn Du. It is marked at the intersection of two field boundaries on the archive map from the National Archives (see **140**). Its position today is not clearly identifiable and any remains that might still exist can amount to no more than a foundation outline, which has been consumed by vegetation and ground slip. The only indicator of its existence and general position is the presence of bricks, some of which remain mortared together, incorporated into an otherwise dry stone-built wall. An outline faintly visible on the earliest high-resolution satellite imagery suggests a position somewhat away from that depicted on the archives map.

Blockhouse 4 lies near the summit of Cefn Du, next to the position of the incline head steam winder engine. It is all but entirely ruined, but with sections of cleanly inward-fallen southern elevation brickwork, and remains of a few firing ring holes. Like all other blockhouses, it was built on stone foundations, the external dimensions of which measure 6m by 5m.

Above: ruinous remains of blockhouse 4, looking west with the transmitter buildings much lower down the hill, top centre left. A trace of the long inclined trackway is visible beyond the highest point of the ruin.

Blockhouse 5 was covered earlier, at Appendix IV, due to the focus placed upon it by earlier studies and the extraordinarily poor assessment of it, leading to incorrect conclusions not only about it, but all other blockhouses. Further understanding of the blockhouse has, however, been gained during 2023.

Above: aerial drone view of blockhouse 5.

The firing ring consists of eight holes, spaced by 36cm/14 inches on the WNW and ESE elevations. There are six holes on the SW elevation incorporating the doorway – three either side of it. There are eight holes, spaced at 15cm/6 inches or one brick width on the NNE elevation.

The recess, being of a size to accommodate a 3 inch thick timber, for the joists of the loft floor, has its lower edge at 6 feet above the ground floor, and lies immediately above the top of the doorway aperture and top of the firing ring apertures.

Blockhouse 6 lies at the very summit of Cefn Du, adjacent to the modern triangulation station pillar. It is seen in archive images of 1923 (see **H5**) to have already become substantially derelict, with no roof and collapsed walls. Today, it is a mostly collapsed structure, though its outline and some of its features, such as the porch, remain clear. Its external dimensions are 6.3m long by 4.63m wide. Its northern and eastern elevations are of stone, some 45cm thick, but its southern and western elevation appear to have been mostly or wholly of brick. A simple porch wall, with open sides, lies 74cm in front of the western elevation's doorway, as it did at all the blockhouses, in this case being largely of stone, with brick corners and being some 46cm thick and 2.31m wide.

Left: blockhouse 6, eastern elevation to left, northern to right.

Blockhouse 7 is positioned along a long, raised, stone-built trackway bed across the moorland that runs all the way from the reservoir near the transmitting hall at the western extremity of the Marconi site to the summit of Cefn Du. Its location was to the rear of the original, 1914 antenna, fairly close to the row of 32 wire tensioning pillars. It is now a fairly prominent, but almost entirely ruined feature in the landscape, amounting to a reasonably well-defined stone foundation outline, a small section of surviving southern elevation and the open porch wall. The external dimensions are 7.70m long (with slight uncertainty due to overgrowth) and 5m wide. The walls are three brick widths wide, at 34cm. The stone-built porch wall is 48cm thick, its internal separation from the western elevation of the blockhouse (the 'gap') is 73cm. Much of the blockhouse walls are now spread as individual bricks around its perimeter, notably downhill, to the west.

Blockhouse 8 is located along the transmitter hall-Cefn Du summit stone-built raised trackway, now simply a pile of stone and some brick, with a stone foundation, with possible remnant evidence of a slate damp-proof course as clearly seen at, for example, blockhouse 1. The external dimensions, though overgrown, are approximately 7.2m long (as measured at the eastern elevation), and 6.1m wide (as measured at the southern elevation). This blockhouse is unusual in that it is divided internally by ca. 47cm-thick stone walls into three cells or rooms of 2.2m internal width (southernmost cell), 2m (centre) and 1.6m (northern cell). Brick fragments incorporated into the foundations of these dividing walls and the lack of keying-in, suggest they were modifications carried out after WW1 was over, or later, possibly as some form of agricultural shelter or store. There are no convincing remains of firing holes, but there are very poor suggestions of them from angled cement elements.

Right: sparse remains of blockhouse 8, looking north-north west. Southern elevation to left of photo.

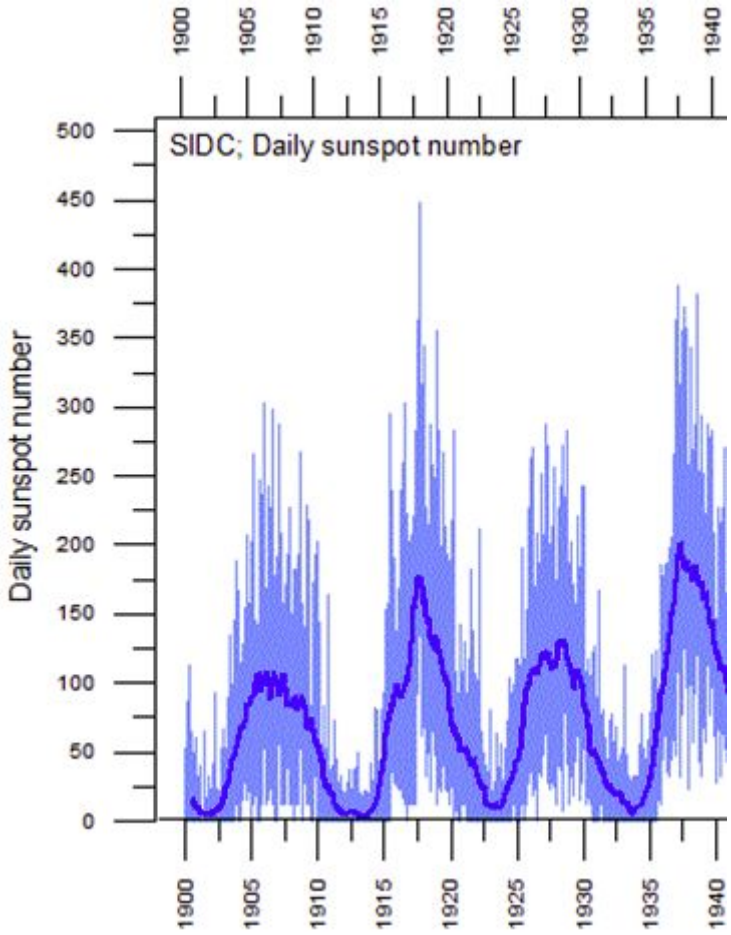
Blockhouse 9 (left) lies half-way up a low hillside overlooking the transmitter buildings. It lies in a ruinous state, with only its southern and, to a lesser extent, northern elevation being in any coherent form today. The western elevation, facing the transmitter buildings, measures 7.32m long. Its southern elevation measures 4.42m long, its eastern elevation measures 6.9m, being 42cm shorter than the western elevation due to the inward-angled northern elevation. There are poor remains suggestive of firing holes in the form of angled brick and slate used to 'roof' the fluted firing apertures.

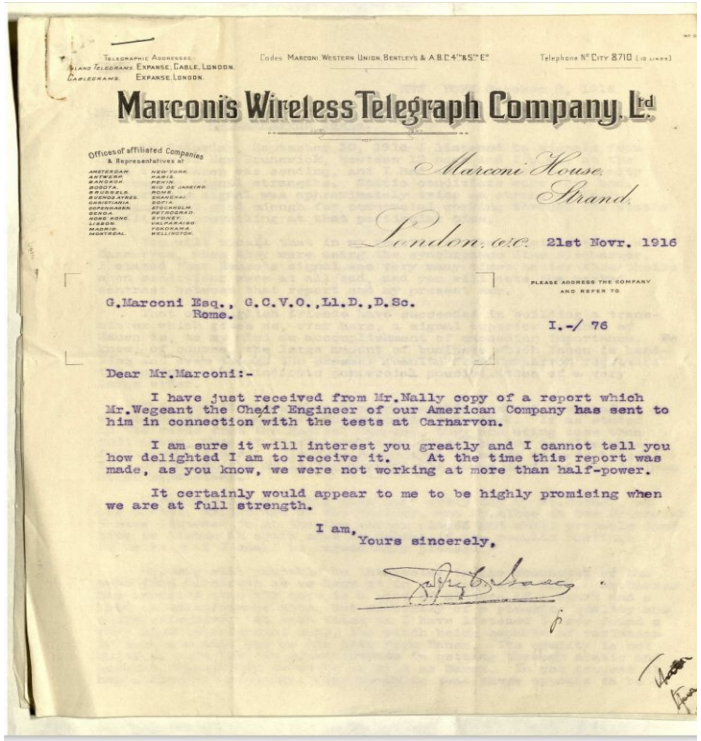
Blockhouse 10 lies 30 metres below blockhouse 9, adjacent to the Marconi Company's property boundary (blockhouses were built wherever the government deemed it necessary to protect the site, and were not limited by Marconi's property boundary) and the two reservoirs. This is second only to blockhouse 3 in its ruined state, being reduced to little more than a foundation appearing as a grass-overgrown mound. Stone and brick elements are, however, evident on light localised excavation, and bricks of the type used for the blockhouses are today incorporated, and have clearly been so incorporated for a very long time, fairly extensively in the wall adjoining the site. The external dimensions of the blockhouse are fairly reliably measured as 7.6m long (southern foundation) and 7.3m wide (western, transmitter-facing elevation). Without extensive excavation, which is unlikely to be very productive, there is no surviving evidence of firing holes nor, indeed, of much else.

Tests at Carnarvon.

The following correspondence, from the end of November 1916, details quite subjective receiving tests of Carnarvon's signal at New Brunswick. This was during the middle part of the Great War, when Marconi's was unable to make commercial gain from its station, being under the control of the Admiralty.

Note the reference to bad 'static' conditions. The solar cycle (number 15 since 1755, when consistent records began) was reaching its peak at the end of 1916, where solar disturbances would have been relatively frequent. The cycle produced disturbances that caused significant damage to telegraph cable and railroad systems in each of the years 1918-1921 (solarstorms.org, accessed 10/6/2023).The plot below shows the absolute and averaged sunspot number for 1900-1940. The peak of cycle 15 (second from left) occurred in August, 1917 – a few months after the tests were conducted.





Telegraphic Addresses: Marconi, London. Inland Telegrams: Expanse, Cable, London. Cablegrams: Expanse, London.
Codes: Marconi, Western Union, Bentley's & A.B.C. 4th & 5th Ed. Telephone No. City 8710 (10 lines)

Marconi's Wireless Telegraph Company, Ltd.

Offices of affiliated Companies & Representatives at:
AMSTERDAM, ANTWERP, BERLIN, BOGOTA, BRUSSELS, BUENOS AYRES, COPENHAGEN, GENOA, HONG KONG, LISBON, MADRID, MONTREAL, NEW YORK, PARIS, RIO DE JANEIRO, ROME, ST. PETERSBURG, SOFIA, STOCKHOLM, PETROGRAD, SYDNEY, CHICAGO, YOKOHAMA, WELLINGTON.

Marconi House,
Strand,
London, W.C. 21st Novr. 1916

PLEASE ADDRESS THE COMPANY AND REFER TO

G.Marconi Esq., G.C.V.O.,Ll.D.,D.Sc.
Rome.

I.-/ 76

Dear Mr.Marconi:-

I have just received from Mr.Nally copy of a report which Mr.Wegeant the Chief Engineer of our American Company has sent to him in connection with the tests at Carnarvon.

I am sure it will interest you greatly and I cannot tell you how delighted I am to receive it. At the time this report was made, as you know, we were not working at more than half-power.

It certainly would appear to me to be highly promising when we are at full strength.

I am,
Yours sincerely,

Oxford Special Collections, Marconi.198

NEW YORK October 2, 1916

Mr.E.J.Nally.
Re:Carnarvon Tests.

On Saturday, September 30, 1916 I listened to signals from Carnarvon at New Brunswick, bewteen 12 noon and 1 p.m., at the same time Nauen was sending, and I had an excellent opportunity to compare signal strengths. Static conditions were very bad. Carnarvon's signal was approximately twice as strong as Nauen, although not good enough for commercial working through the static conditions prevailing at that particular time.

You will recall that in my reports of the original tests with Carnarvon, when they were using the synchronous disc discharger, I stated that Nauen's signal was very many times better that theirs when conditions were at all bad, and you will note the marked contrast between that report and my present one.

That our English friends have succeeded in building a transmitter which gives us, over here, a signal superior to that of Nauen is, to my mind an accomplishment of exceeding importance. We know, of course, the large amount of business which Nauen is handling and even though the present results from Carnarvon represent the maximum, they indicate commercial possibilities of a very large order.

This result means that through anything except very bad static conditions much business could be handled. If as stated in the cable from the English Company, they are using less than full power, then it is reasonable to expect better results when full power is used. In this connection it would be very helpful if I could get the daily log showing the power used and the various other conditions.

Observations are being made here every day by Mr.Bucher, at the School, Mr.Farrand at the Factory, and Mr.Albee at New Brunswick I have listened in at the two latter placed and shall probable find time to listen in again once or twice; if the results continue to be as good I shall be exceedingly pleased.

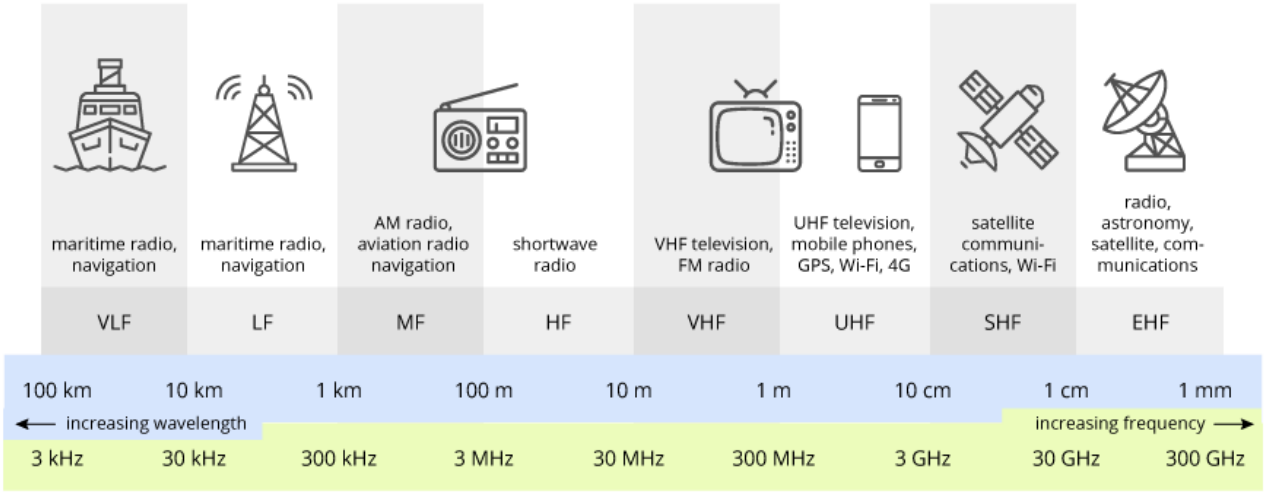
Mr.Gray will probably be interested in the character of the note from Carnarvon as we hear it in our apparatus here. Mr.Bucher has reported that the note is a sort of mixture of a spark and a beat or interference note, but generally of a pleasing quality and quite effective. At such times as I have listened I have found a very good interference note, the pitch being capable of variation in much the same way as the note from Nauen. Its quality is not quite so pure but its effectiveness in getting through static and general readability is quite as good as Nauen. In one respect it has a distinct advantage over Nauen in that there appears to be a

complete break between dots and dashes, whereas Nauen does not break the entire energy when he opens the key, with the result that the space between the dots and dashes is not a complete silence, since a certain amount of energy is being radiated all the time.

Due to the fact that the oscillating valve amplifies a weak signal in greater proportion that a strong one, this reduced energy is heard out of proportion to the full radiation, with a result that Nauen's signal is not nearly so easy to read as it would be if the break were complete.

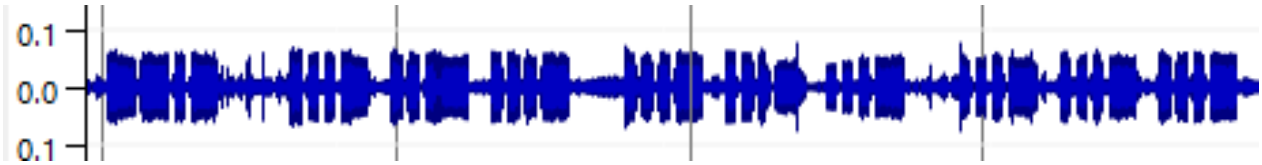
I am awaiting with interest your return and hope that you may bring with you full information relative to the Carnarvon transmitter, as we need it very much indeed.

(Signed) R.A.Weagant.



The radio portion of the electromagnetic spectrum. Typical Carnarvon transmissions were at the upper VLF to lower LF range. Original image source unknown.

The following is a trace from a 17.2kHz VLF transmission, using an Alexanderson alternator installed in 1924 and a multiple-tuned antenna array at SAQ, Varberg, Sweden, on 30th June, 2024. Part of the standard 'VVV VVV VVV de SAQ' preamble message, keyed by a punched paper machine reader, is clearly seen. The signal was received on Anglesey using a 18m-long amplified loop antenna and software-defined receiver.



Dramatis Personae

Above: Nevile Maskelyne (not to be confused with his father, of the same name and profession!)

Right: Guglielmo Marconi at the wireless set aboard his beloved steam yacht, 'Elettra' ca. 1920. The distant but inoccuous appearance hid a man who, over time, became an active participant in Mussolini's fascist regime and blocked Jews from entering the Royal Academy.

John Ambrose Fleming.

Henry Joseph Round

Prince Ludovico Spada Veralli Potenziani, second fascist governor of Rome (1926-1928).

During 1914, Marconi completed a vast wireless antenna on the wild slopes of Eryri, north Wales. The ‘Carnarvon’ station became the most important British VLF wireless transmitter, acting in concert with its receiver site at Towyn. On September 22nd, 1918, Carnarvon sent the first ever direct, non-relay message between the UK and Australia, chosen to rally Australian troops. Eventually, Carnarvon operated three separate VLF antennas, identified as Numbers 1-3 and operating from transmitter callsigns MUU, GLC and GLJ. By 1939 – just 25 years after the great iron masts appeared on the slopes of Cefn Du – the era of VLF was over, replaced by short-wave technology, and the station dismantled.

As MWTC commented around 1921, “the history of the Carnarvon station is, in large measure, the history of the Marconi Company’s work on high-power transmitters”. It was where the latest transmitters were installed and where Marconi engineers gained experience in their operation before being deployed to other stations of the Marconi ‘Empire Scheme’ around the world.

This book charts, for the first time, the detailed development of the Carnarvon station, drawing on the only field and archive work ever done on the site. Most of the photographs included here have never been published. The text has swept away decades of poor and often incorrect information published in earlier writings. It has yielded a complete understanding of the entire antenna field and provided the impetus for the long-overdue legal protection of this globally-important industrial heritage site.

Praise from the modern wireless community:

”A significant and invaluable contribution to the fusion of scholarship in radio archaeology and radio history." - Dr Alexander Magoun, IEEE Historian

"It's fascinating; for me it opened up a whole section of radio history that I knew little about."
Peter C. Laws, VE2UWY/N5UWY

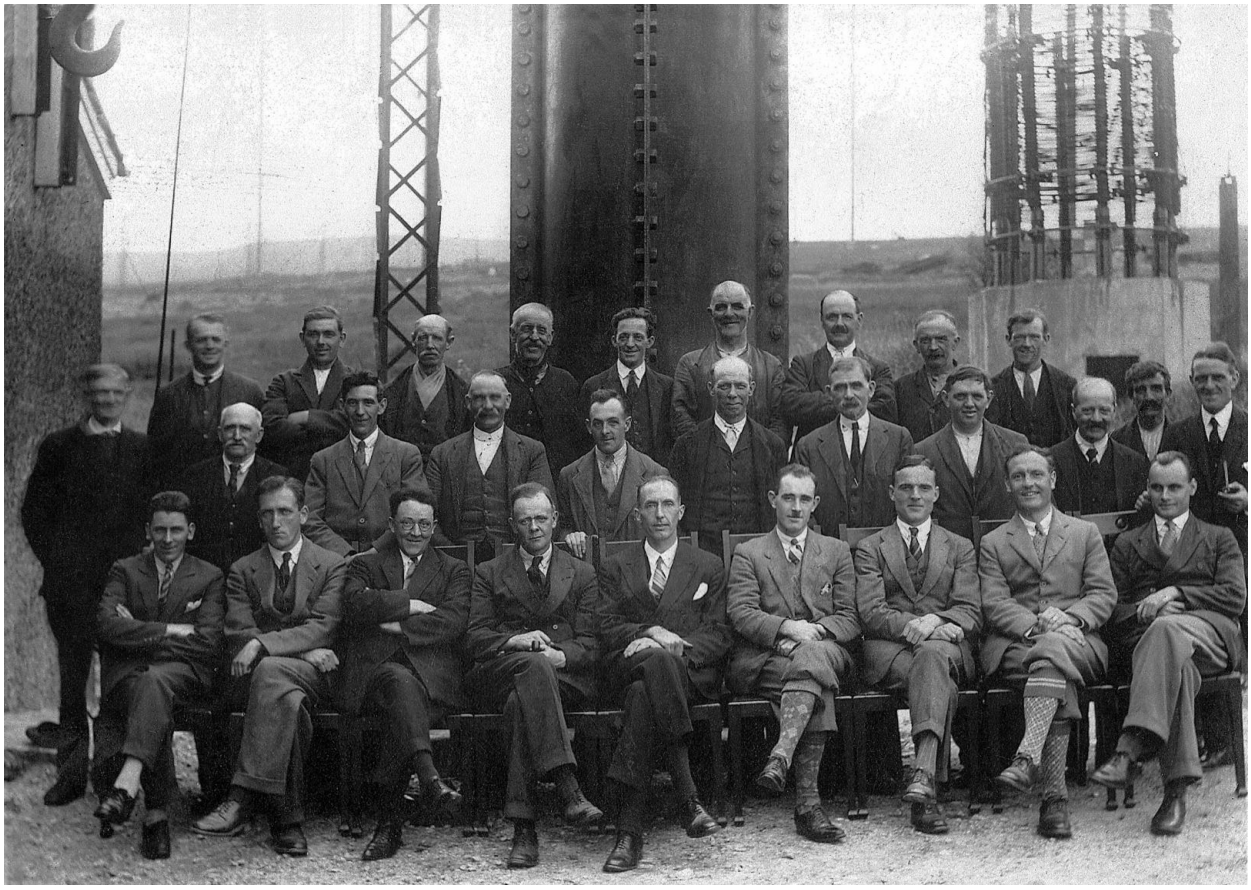
"A surprisingly good read!"
Les Hayward, MW0SEC, former electronics engineer.

“Highly recommended to any Marconi fan!” Bill Ruck, Marconi Bolinas transmitter and the RCA Point Reyes receiver sites, USA.

“Wow! I’m impressed!” Fredrik Wiklund, Chairman, Alexander Association, UNESCO World Heritage Site of ‘SAQ’ VLF station, Sweden.

Your book is AMAZING! Michael Schultz, WH6ZZ, researcher of Marconi’s Kahuku station, O’ahu, Hawai’i.

John Rowlands has held a life-long interest in wireless, ever since turning on an old valve-based Philips 151U receiver in the shed. A licensed amateur radio operator since 1997, John is a retired microbiologist and now enjoys wandering over and under the north Wales landscape, promoting understanding of the area’s often overlooked heritage – of which the Marconi Carnarvon VLF site was a glaring example.



The engineers and staff of Marconi's Carnarvon Station, 1924. Then Engineer-in-Charge, R.N. Barrington, sits at front row, centre (white handkerchief). This photo has likely never been previously published and is part of an invaluable album of images believed to have been taken by Barrington and saved from the dustbin by a widow of a man who contacted Paul M. Hawkins to see whether he might be interested to receive it. The album is likely to be donated to the Oxford Bodleian Special Collections in due course. The transmitter hall gable and large hook, likely used to install transmitter equipment, is glimpsed at far left. A narrow lattice mast that supported part of the elevated ground system is seen behind the man at rear row, third from left. The scene is dominated by one of two sectional iron masts of what is believed to have been a ground system catenary support. At far right, rear, the octagonal concrete base and ground tuning inductor coil is seen in good detail for the first time at this station.