The most influential Royal Engineer - Lt. Adcock's famous invention.

There aren't many who's contribution to the modern world endures like Adcock's invention. His radio antenna system patented at the close of World War One is still 'high tech' in the secretive Signals Intelligence Direction Finding community. This invention opened up navigation for commercial aviation including the extraordinary trans Pacific route for the China Clippers in the 1930s. It featured in the Chain Home Radar system and Huff-Duff equipment of WWII that were so significant in both the 'Battle of the Atlantic' and the 'Battle of Britain'. But who remembers this Royal Engineer - not even Wikipedia?

Radio (then known as 'wireless') developed rapidly and found applications in a number of distinct fields. Initially it was used for telegraphic communications. As early as 1907 Otto Scheller patented a radio beacon transmitter for marine navigation. Radio Remote Control applications and 'Drones' emerged under the command of Eric Robinson V.C. in WWI. Of course, the ancient art of eavesdropping also took to this new medium. For surveillance, these new technical curtain twitchers could discern more than just the coming and going of other peoples transmissions, They could potentially listen in to the information, recognise who was transmitting, at which frequencies, in what manner and with Direction Finding (DF) Loop Aerials, identify where messages were coming from. They might even guess who the intended receiver was. In military terms these abilities developed into the new disciplines of Electronic Support Measures (ESM), Traffic Analysis and Signals Intelligence (SIGINT).

Loop Aerials had been greatly improved by the work of two Italian engineers, Ettore Bellini and Alessandro Tosi who from 1910 were based near the Tuileries Garden in Paris. They raised a number of patents, fixing the large loop antenna so they could be made even bigger while reducing the rotating element, their 'radiogoniometer'. The strenuous efforts undertaken to improve DF also illuminated the scientific understanding of radio propagation and the subtleties and mysteries of its behaviour. In addition to SIGINT uses, passive DF systems along with active beacons became the twin basis of the first commercial navigation aids.

In WWI Colonel Baynton Hippisley developed the first British Wireless Interception (WI or 'Y') Stations and Captain Henry Round of the Intelligence Corps made further great improvements to loop Direction Finding equipment, introducing these on various sites on the Home Front and in France. The British Expeditionary Force established Wireless Observation Groups on the Western Front but their incessant radio reception problems were logged much like this entry ….. "28/7/1918 Strong and continuous 'Atmospherics' and

work seriously handicapped". These 'Atmospheric' problems were compounded by such strange phenomena as the 'night effect' and 'coastline refraction'. In 1918 a significant source of DF 'night effect' error that plagued the Loop Aerial's of the time was identified and a solution devised by one of the officers with the Third Army Wireless Observation Group. He was a Royal Engineer, Lieutenant Frank Adcock. His new radio direction finding invention which he submitted as a patent application from France in 1918, was published in 1919.

At this exact time the radio world was focused upon the new narrow band continuous wave generators. These enabled multi station broadcast radio services to be started, beaming programmes to the populous who were hungry for their own home radio sets. In those few years of the early 1920s the world began to 'tune in' for the first time in history.

By 1924 investigations by the British Radio Research Board confirmed that Adcock's invention had the right answer to the 'night effect'. He used four vertical aerials, similar to those of Otto Scheller original 1907 patent. Adcock's novel and crucial addition was to minimised and cancel out the disruptive multipath signals causing the 'night effect' that he had identified were being detected in the horizontal ground interconnections.

Devices with sufficient power to transmit at ever higher frequencies would be devised eventually reducing the size of the required antenna. However, for many years transmission frequencies were low so Adcock's DF installations remained large and immobile, requiring a substantial amount of flat land. Due to the size and cost of Adcock's system, for many years throughout the 1920s and 1930s direction finding facilities continued to use the inferior loop aerials, as did those that were required to be mobile, such as those employed to locate local clandestine and illegal sources.

However, without accurate navigational aids and reliable radio communications disastrous expeditions continued to be a regular occurrence. Many of these are the perpetual mysteries of aviation legend. What happened to all those who flew and were lost in these times? For instance Princess Anne of Löwenstein-Wertheim-Freudenberg and her companions lost over the Atlantic or those missing in the Pacific trying to win the Dole Derby. Even later, in 1937, Amelia Earhart was lost over the Pacific. And again, in WWII, why was Amy Johnson so grossly off course when she died?

One of the most significant British applications of Adcock's invention had its roots in WWI. In 1916, soon after they were married, Robert Watt started work with the assistance of his wife Margaret, at the Meteorological Office Radio Station, Smallshot Hill, Stanhope Lines in Aldershot on a mission to

detect lightening from its radio emissions. Watt, R. A. W. with E. V. Appleton and J. F. Herd had just published their timebase patent for the Oscillograph when the Committee on Wireless Direction Finding was created in 1925 and research work started at Farnborough and Gosport. In early 1926 Watt (who didn't hyphenate 'Watson-Watt' until 1942) and Jock Herd presented an extensive paper on their use of a cathode ray tube (CRT) to ‘instantaneously’ display the bearing of a source detected by an Adcock Array – entitled ‘An Instantaneous Direct-Reading Radiogiometer’.

This Watson-Watt / Herd system was a huge potential leap in performance of DF equipment for the passive detection and rapid identification of the source of radio energy but it was not to be developed for over a decade. The substantial ground station required to accommodate Adcock’s aerial array and the custom made, rare and expensive CRTs of that time prevented this. In addition to these considerations, to be used as a navigation aid, ships and aircraft would have to be equipped to transmit call signs so that their bearing could be identified by the Adcock receiver and radioed back to them from the detection stations.

Added to this, in Britain from 1919 the ‘Ten Year Rule’ prevailed and this was followed immediately by the Great Depression so military development was out of favour and as a consequence, out of substantial funds well into the 1930s. Available funding went into acoustic mirror research for military aircraft early warning. Adcock’s system was not affordable as an aviation navigation programme at that time.

When British research into the use of directional radio eventually resumed it used loop based technology for a navigation experiment. In 1929 a high powered transmitting loop beacon, under the guise of a mercantile marine project, was erected at Orford Ness. Although of dubious use to shipping, the facility provided experience in the use of radio beams by the RAF which was the primary, thinly disguised, real motivation for its creation. For military use however, such transmitting navigation aids were susceptible to jamming.

The Orfordness DF ‘Black’ Beacon

This project was extended in 1933 when a second DF tower was created in Cove, near the Royal Aircraft Establishment at Farnborough. These two transmitters used the same frequency (288.5 kHz) but transmitted at alternating 5 minute time intervals. The loop on top of the tower rotated at 1 rpm, precisely 6° per second. The ships (and aircraft) just needed their receivers and stopwatches to derive their bearings from each transmitter. These could be calculated from the elapse time between the signal that was transmitted each time the loops passed their North position and the receipt of the ‘null’ in the radiation pattern of the swept signal.

However, loop aerial polarisation errors still made their use unreliable and these errors were now commonly referred to as the “air-plane effect".

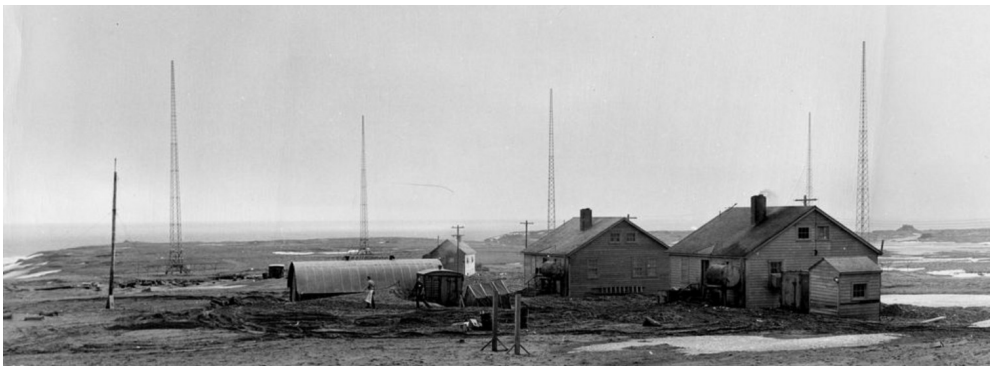
Pan American, that pioneering airline, undertook the most notable early large scale exploitation of Adcock’s invention. In 1935 they created island stops across the Pacific, including the then uninhabited and remote Wake Island. Their work was truly ‘groundbreaking’. Construction teams and materials were delivered on the steamer ‘SS North Haven’ to each base prior to the inauguration of their revolutionary China Clipper route, a commercial airline service made possible by the creation of these island bases. The large Oceanic distances between these bases was well beyond the reliable range of beacons and beams. For this huge leap in air transport development Pan Am relied upon the Adcock’s system of direction finding. Each of these island stations had 16, 40 foot antenna masts with 35 feet of the poles above the ground, plus another five feet in the ground. The Pan Am archive website still says…

> *"The Adcock direction finder was phenomenal for its time. A radio operator in an airplane could hold down his transmitter key, and a ground operator could get a bearing within 1 degree at a range up to 1,500 miles. With bearings from two stations, the Clipper could fix its position with great accuracy. One perfect night a station in Alameda got a bearing from a Clipper between Guam and Manila, but that was exceptional."*

But this was not just a commercial aviation venture as these Island bases had a military value in those crucial years leading up to WWII. The ‘passive and covert’ information gathered on shipping movements in the Pacific from these stations in the lead up to war in the Pacific must have been a great source for the US intelligence services.

The demand for accurate air navigation increased as commercial aviation developed. An extensive system of radio beacons developed, transmitting beams in multiple known directions for suitably equipped aircraft to follow. In North America the air mail service of the 1930s spurred on this development of reliable cross country aerial navigation. Extensive networks of beacons

were developed, the Low Frequency Radio Range or Adcock Range in North America, the Elektra Sonne system in Germany and the Consol in the UK. Accurate navigation with these Radio Ranges in the busiest transportation hubs and in some of the most remote places on the planet was the start of today's international air traffic control infrastructure.

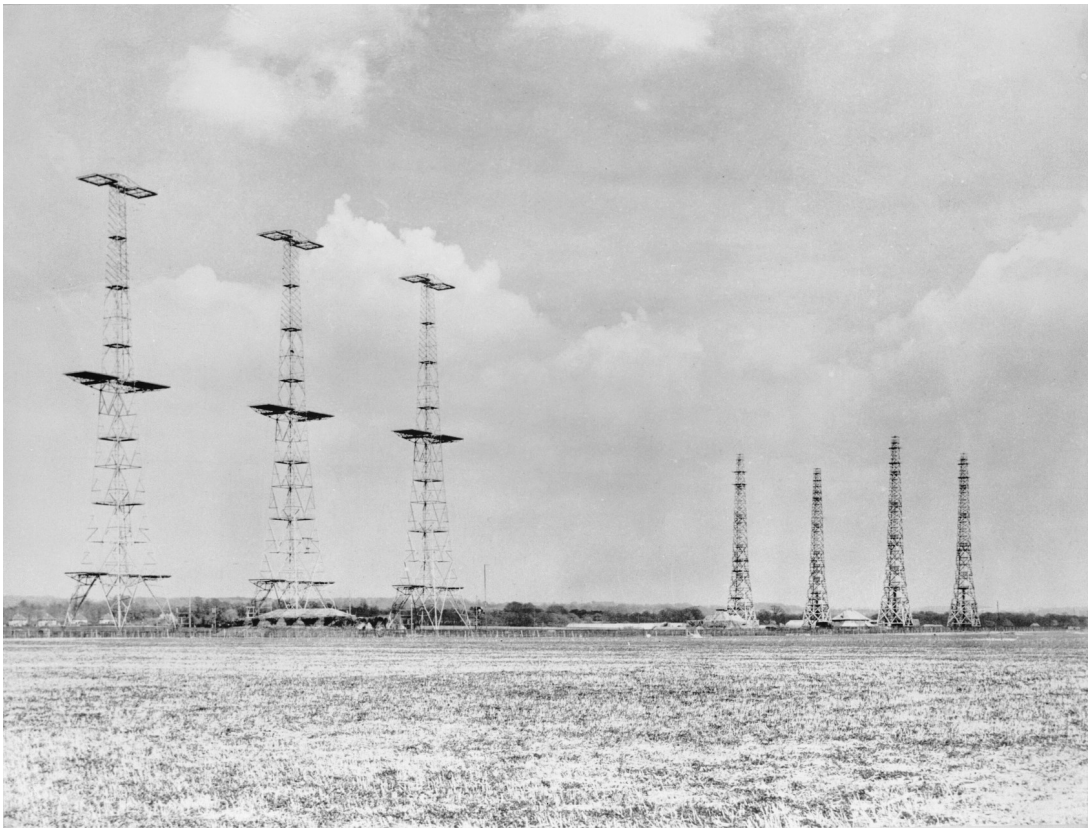


The Adcock Radio Range Station on Chirikof Island, Alaska 1946

In the last few desperate years before the war Watson-Watt had a team at the Research Station at Bawdsey Manor in Suffolk that were in a frantic race to develop a British radio early warning detection system in case the ever growing Luftwaffe launched raids across the North Sea from Germany. This urgent secret RDF programme had superseded the acoustic mirror development following the success of an experiment carried out on the 26th February 1935. This hastily organised experiment had detected radio reflections from an aircraft using a trial aerial installation set up in a frozen field 10 Km from the powerful BBC transmitter at Daventry that it was using as its radio source. The ability to detect the tiny aircraft return signal (technically 10^{-19} of the transmitted energy) was by no means certain but as a publication in 1937 confirmed "....In direction-finding, the Adcock aerial is a British invention of established worth." and so it would prove to be again in this new RDF application to be known as 'Chain Home'.

The fall of France in 1940 put the Luftwaffe bases in an unexpected location; right on England's doorstep facing this famous iconic Watson-Watt chain of synchronised radar sites that was just barely ready in time before the start of the onslaught that was the 'Battle of Britain'.

This 1945 image of the Air Ministry Chain Home radar installation at Poling, Sussex shows three (of the originally four) in-line 360ft steel transmitter towers, between which the transmitter aerials were slung. On the right are the four Adcock 240ft wooden receiver towers placed in their square formation, with the receiver building in the middle.



Chain Home radar installation at Poling, Sussex

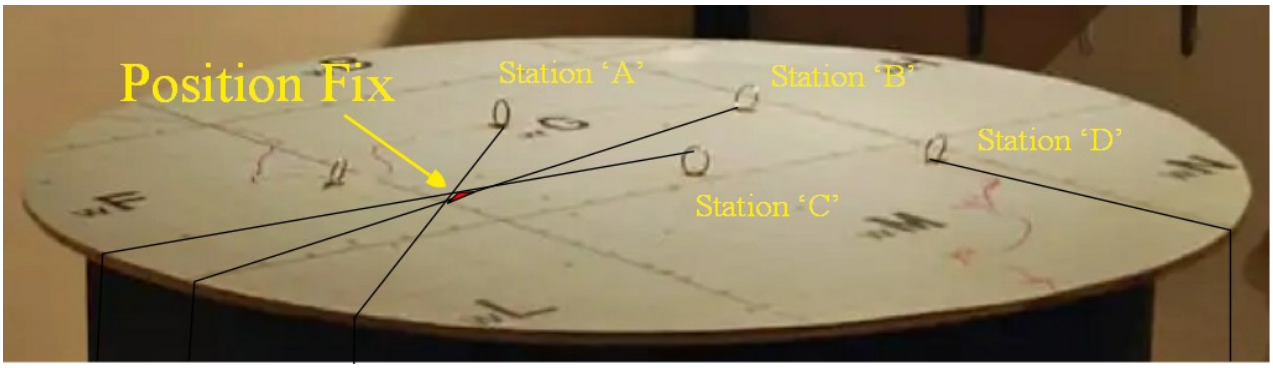
Within his 1935 Patent Watson-Watt references the 1933 paper “Applications of the Cathode Ray Oscillograph in Radio Research” he published with James Herd and Labouchere Hillyer Bainbridge-Bell. In this paper they advocate an antenna of the…..

> “….general type introduced by ADCOCK. That a cathode ray direction finder using such an aerial system will be the only apparatus applicable in the most difficult cases is increasingly evident…….. as a practical direction finder is thus dependant upon its final association with spaced aerials of the Adcock type.”

By 1943 however, the Germans had developed a different antenna to exploit the British system. They used rotatable aerials for their ‘Klein Heidelberg Parasit’ network of receivers. These ‘hitchhikers’ took advantage of the Chain Home illumination of the seas around England’s south-east coast provided by the British transmitters, becoming enemy elements of a widely separated multi site bi-static radar system on both sides of the sea. Being passive, this ‘cheeky’ ‘Klein Heidelberg’ system was not discovered by the allies until the first sites were overrun after D-Day.

The Chain Home detection of the bombers was not the only part of the Hugh Dowding RAF defensive system that used Adcock’s antenna. Another crucial

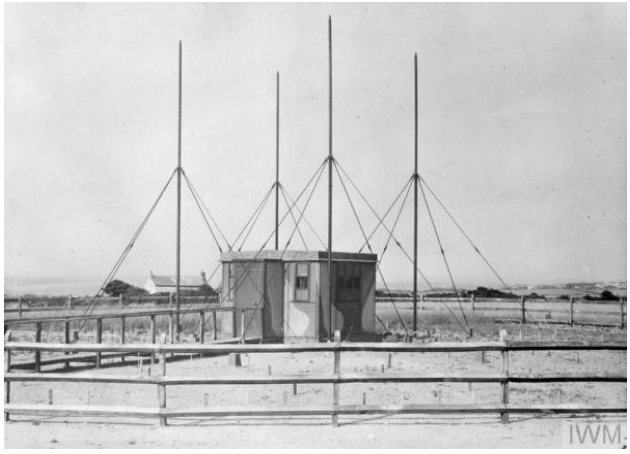
element was the network of High Frequency DF “Huff-Duff” bases tracking the fighters "pip-squeak" transmissions. The fighter’s position was rapidly establishd on small specialised tables from the bearings taken by individual HF-DF stations. One design had strings from each tracking station position leading to the edge of a table that was marked off in degrees. When stretched to the respective bearings provided by each RDF station, the strings crossed at the location of the source, a quick and simple method to ‘fix’ the position.



Tracking the Fighters

The fighter positions could then be relayed to the control centres where, with the location of the incoming enemy raiders they were plotted on those famous large mapping tables (derived from Philip Fooks’ original in Spring Gardens near Horse Guards used in the First World War). Using Henry Tizzard ‘Tizzy Angle’, the RAF fighters were then guided by radio instructions to intercept the German bombers.

Adcock DF stations around the coasts of Britain and North America detected the U-Boat transmissions enabling them to be targeted by air and sea throughout the Battle of the Atlantic. As CRT availability improved these stations were upgraded providing virtually instantaneous direction readings even though the Kriegsmarine introduced ever shorter transmission ‘bursts’ in their futile attempts to avoid detection.



Adcock array WWII Naval “Huff-Duff” station (IWM)

Wacław Struszyński worked on Direction Finding in Poland before being evacuated to Britain in 1940. His team produced a complex Huff Duff aerial that was used on ships. The Royal Navy called it the ‘Birdcage’ and with it they took effective DF to sea against the U-boats.

The famed work of Bletchley Park and its decodes relied upon the steady stream of ‘raw material’, the messages intercepted by the extensive network of the listening ‘Y’ Stations. Many of these included Adcock “Huff-Duff” equipment. The ‘’Y’ Stations provided the context to make sense of the messages; matching Bletchley’s decodes to their transmission sources and locations. These RDF networks tracked the movement of mobile enemy unit’s adding to the intelligence picture and revealing the redeployment of enemy assets. Over time from these data an appreciation of the ever changing order of battle of the enemy forces emerged.

As powerful higher frequency sources were developed after WWII the Radio Ranges started to be upgraded and expanded using very high frequency (VHF) equipment. The importance of Adcock’s antenna and RDF continued throughout the 1950’s improving military, law enforcement, search and rescue, surveying, interference location and other operations. They aided the West’s nuclear airborne deterrent fleets in operations from the start of the Cold War and unlike Radar, the passive DF technology, advanced the use of SIGINT.

Sites such as Kikai-jima in Japan used an Adcock HF-DF system and Adcock equipment such as the DF-A0257 compact SIGINT DF Antenna and the range of antenna from such companies as RDF Products are available today, many using his methods with extensive variations.

But Frank did not get to share in any of this, and amazingly, his biographical details are hardly mentioned in published material even though he had a full, long and very interesting life. Indeed, some authors have even mistakenly identified him as Frank Ezra Adcock, the classical historian who was a cryptographer in both World War I and World War II. But Ezra was a Navy man. Our Frank was Army.

If by this point you may require further proof of the ubiquitous proliferation of equipment based upon Adcock’s invention, a brief on-line search will provide more examples, detailed descriptions and technical explanations. Frank’s antenna is well known but he has been an enigma - until now. Let us meet the man.

Frank Adcock MBE DSc 1892 - 1965

Frank was a Suffolk lad. He and his younger sister Gertrude grew up in St Matthew's Street, Ipswich where their parents, Francis and Alice Adcock had a greengrocers business. In September 1905, these two young children suffered the loss of their mother who died when their brother Alvin was born. A year later their father, now in his forties, met Agnes and they married. By 1911 the family had moved to Fore Street where Francis had started a second hand furniture business. Meanwhile the 18 year old Frank had gained himself a position as a student teacher.

Then this boy from a working class background gained a place at a prestigious University, a slightly unusual achievement in pre-World War One England that was perhaps an indication of his talent and potential. At his graduation he became the proud recipient of a Science Degree, with First Class Honours from King's College.

In August 1915, just before his 23rd birthday he joined his peers in the war. He had been in the Officer Training Corps while attending the University of London, one of the 1000 or so students who had joined the OTC since its' beginnings in 1909. Now this budding scientist left academia for 'the duration' and a life in the military.

Corporal Frank Adcock (Service Number 33962) of the Royal Engineers was commissioned as a Lieutenant in April 1916. Reflecting on his wartime experiences in the 1950's, Frank was quoted saying…..

> "in the First World War, he was in charge of an observation group watching enemy activity and intercepting signals. Each sunny morning German planes went over to watch artillery action. The enemy planes always followed the same procedure. As a result, they became 'easy meat' for the British."

Despite this observation of apparent British supremacy in the skies, complacency does not seem to have been in Frank's nature as he identified the element of the radio reception disrupting their work that led to devise the solution and submit his famous patent.

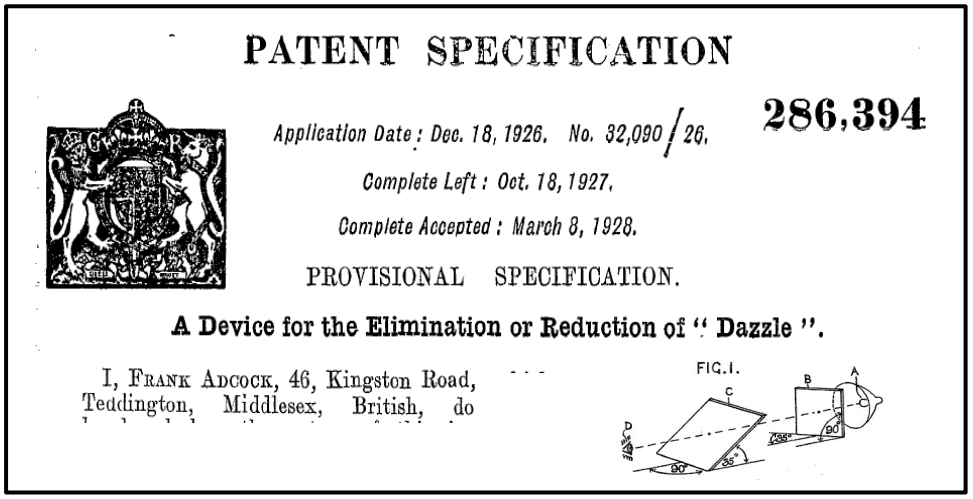
At this time, just like aviation, the world of wireless was young and in a whirlwind of research, discovery and development. The advances were such, that by 1918, the kit operated by Adcock and his soldiers would have been almost unrecognisable to that used in his earlier days of their service in 1915. The applications and operational complexities expanded. One aspect of their intercept work attracted a degree of resentment and hostility from their associates as it involved spying on their own to ensure radio procedural correctness.

By 1918 Lt. Adcock was in his third year in France. That August he submitted his patent application in which he stated that he was a member of the No 3 Army Wireless Observation Group, part of the 3rd Army of the British Expeditionary Force. His patent was published in 1919 and Frank was awarded an MBE, for outstanding scientific work while on service.

After the war he went to the Royal Technical College, Glasgow, probably as a metallurgy research student under Professor Cecil Desch. He would not be engaged professionally in radio again in his civilian career but as we will see, he retained a lifelong interest in the subject. Like many ex military with their wartime experience, he became a member of the local radio club when it reformed in January 1920. On Wednesday, 4th February 1920 at 30, Gordon Street, Glasgow, "Mr. Adcock gave a most interesting lecture on Directional Wireless" to the Glasgow and District Radio Club.

He left Scotland with the National Physical Laboratory (NPL) Metallurgy Division when it was located at Sheffield University. In 1922, he gained a post as a scientific officer at the NPL in Teddington under the Directorate of Scientific and Industrial Research - a crucible of metallurgy research!

In addition to his antenna, Frank's other missed opportunity to win fame and fortune was his 1927 Patent to reduce dazzle using polarised light in which he states…. "Observers can look through windows or spectacles.." The well known 'Polaroid Corporation' wasn't founded until 1937.



PATENT SPECIFICATION

286,394

Application Date: Dec. 18, 1926. No. 32,090/26.

Complete Left: Oct. 18, 1927.

Complete Accepted: March 8, 1928.

PROVISIONAL SPECIFICATION.

A Device for the Elimination or Reduction of "Dazzle".

I, Frank Adcock, 46, Kingston Road, Teddington, Middlesex, British, do

FIG. 1.

He married Nancy in 1931 and they had three children. He gained his doctorate of science at London University in 1934 and held senior posts until 1945, serving in the war in the National Physical Laboratory Radio Division.

Frank was bound for Australia but his aerials got there before him. Following the enquiry into the Kyeema air crash that had shaken the country, an Adcock cathode ray direction-finding station was installed near Liverpool, New South Wales in 1939. The newspapers reported that it…..

> "replaced the Bellini Tosi system, which was inaccurate for about an hour before and after sunrise and sunset. It will be the first of a series of Adcock DF stations throughout Australia."

In 1948, the board of B.H.P. (the Broken Hill Proprietary Company - "the Big Australian") invited Frank to advise on the organisation of their research work. He took up the post of Chief Research Officer based in Newcastle, New South Wales and the company announced that Dr. Frank Adcock, who had been Professor of Metallurgy at the Indian Institute of Science, Bangalore (South India) for some time, has been engaged to take charge of the research activities of BHP. (The Bangalore placement had been a two year NPL secondment.)

It is just possible that Frank hadn't been fully aware of the widespread use of his 1919 invention until his move to the Pacific area where Pan Am had led

the way to trans oceanic navigation. At this time the revelations of the secret role of Radar in the war and the post war roll out of new Air Transport radio systems including Adcock technology were in the news.

In March 1949, Reuter reported that Professor Frank Adcock, of Memorial Drive, Newcastle, New South Wales, whose research led to the radio direction-finding installation known as Marconi-Adcock, claimed a Crown award for his invention before the Royal Commission of Awards. The patent renewal fees had not been paid since 1922 and the grant had expired in 1934. The enquiry stated that the first British Government installation of the Adcock equipment was in Norfolk in 1932, and many installations had since been made. The Crown contended that the claim could not be considered but it was difficult to see how the merit of an invention was diminished by the fact that information about it had not been kept exclusively in the hands of the Crown, but had been published. The news report ended ‘The commission will give its decision later.”
Note: I have been unable to find out what the decision was but I think an award was unlikely!

Frank’s interest in radio did not wane and in June 1950 he gave an address to the Newcastle Business Men's Club on "Radio in Two World Wars." He said that weather reporting in WWII was done by means of direction-finders, which located lightning and thunderstorms. He constructed one of these sets and travelled throughout England, Wales and Northern Ireland. It was often a nightmare to find one's way about the roads because Germans dropped delayed action bombs. That year he attended the local branch of The Radio Engineers of Australia at its annual Christmas Founders Dinner. Still forward thinking, in 1951, as chair of this organisation he arranged a preview showing of the blockbuster movie 'Destination Moon’ at the local theatre at which about 500 attended. The film was based upon a USA private industry spacecraft going to the Moon – would you believe it!

Frank died in December 1965 in Newcastle, NSW.

Frank Adcock MBE DSc (1892 – 1965)

The WWI Royal Engineer who’s invention shrank the world.

Steve Mills (author : The Dawn of the Drone)

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