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Prof Ewart Farvis and the Secret Radio War

by Dr Bruce Taylor

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Dr Bruce Taylor is an Edinburgh University graduate who began his career with Ferranti Ltd before joining CERN (The European Organization for Nuclear Research) in Geneva for 34 years. Before retiring in 2003, he was the head of the international team that developed the timing, trigger, and control systems for the particle physics experiments at the Large Hadron Collider.

New Year's Day 2021 marks the 60^{th} anniversary of the appointment of Professor Ewart Farvis to the first Chair of Electrical Engineering within the Faculty of Science of the University of Edinburgh. A Regius Chair of Engineering at the University had been founded within the Faculty of Arts by Queen Victoria in 1868, and Electrical Engineering had been taught since 1926. However, it was not until 1941 that the University introduced a degree specifically in Electrical Engineering, and 1948 before the subject was organised as a separate discipline within Engineering.

Farvis

That same year, 37-year old Farvis left his post in the Physics Department of University College Swansea to join Edinburgh University as Lecturer in Applied Electricity. In 1952, Farvis was promoted to Senior Lecturer, and, on 1 January 1961, he was appointed Head of the new Department of Electrical Engineering, a responsibility that he fulfilled with exceptional dynamism and distinction until his retirement in 1977.

Farvis was an inspiring lecturer of electromagnetic theory and, despite his heavy administrative load, he always found time personally to introduce students to the intellectual magic of Clerk Maxwell's equations. This was a significant milestone in their engineering education that was rendered all the more poignant by the fact that Clerk Maxwell himself had studied at Edinburgh University from 1847 to 1850. I knew that, in 1940, Farvis had joined the government's Telecommunications Research Establishment (TRE). I was intrigued by the examples that he chose to illustrate the challenges in high frequency antenna design, such as the reception of radio waves of various polarisations propagating by different paths over the sea. This suggested to me that he might have a particular experience of early warning defence radar, but for 30 years after WW2, he divulged no details of the work on which he had been engaged during the conflict.

Prof Farvis was not the only staff member who complied strictly with the terms of the Official Secrets Act. Dr Bernard Meltzer, a Reader in the Department of Electrical Engineering who joined the university from EMI Research Laboratories in 1955, had also been transferred on the outbreak of hostilities to secret work at the TRE, and, in 1941, he enlisted in the RAFVR.

In 1972, Meltzer was appointed to a personal chair in Computational Logic and, in 1974, he became Head of what later became the University's Department of Artificial Intelligence.

Chain Home Low (CHL)

The veil of secrecy over much British wartime work was eventually lifted in 1974 by the publication of Frederick Winterbotham's book *The Ultra Secret*, which disclosed part of the extraordinary code-breaking activity that had taken place at Bletchley Park. Having opened the floodgates, this book was followed by many more fascinating revelations about a vast range of British technical innovations during WW2, such as Colossus, the world's first programmable electronic digital computer. Colossus had begun working in December 1943, two years before ENIAC came online at the University of Pennsylvania, but it had remained secret for over 30 years.

Farvis at last felt free to speak about his wartime activities, and the experiences which he described were quite remarkable. To create a lasting record, he consented to a long filmed interview with Colin Davidson, who had done his PhD under Farvis in 1960 and lectured at Edinburgh University before moving on to Nuclear Enterprises and becoming Head of Department at Heriot-Watt. Then, in April 1995, Farvis made a public presentation of some of his secret wartime work during an Edinburgh International Science Festival lecture held in James Clerk Maxwell's birthplace in India Street.

It transpired that he had, indeed, worked on radar along with Robert Watson-Watt, the Scotsman who pioneered the British development of this pivotal invention for the radiolocation of aircraft. The first Chain Home (CH) radar stations for the defence of the UK could only detect planes flying at high altitude, a fact that was soon discovered and exploited by the Luftwaffe when they noticed that aircraft on low-flying minelaying missions were rarely intercepted. To counter this, Farvis developed special antennas for the higher frequency Chain Home Low (CHL) system, which could track aircraft flying as low as 500 ft. Over 100 CHL stations were successfully deployed around the south and east coast of Britain, as far north as the Shetland Islands, and they remained in service for over 10 years after the end of the war.

CHL radar installation at Hopton-on-Sea

Knickebein

On 16 October 1939, in the first air raid on Britain in WW2, a Heinkel He 111 medium bomber was shot down by a Spitfire of 603 (City of Edinburgh) Squadron over the Firth of Forth. When the plane's radio equipment was taken to RAE Farnborough for examination, the technicians were surprised to find that the Lorenz blind approach receiver from the aircraft was a 7-valve superheterodyne of much higher sensitivity than the 2-valve set that was adequate for normal service. Later, captured aircrew from another He 111 were overheard saying that no matter how diligently the British searched their plane they would never find their bombing navigation equipment, implying that it would be overlooked because it was right under their noses.

Prof Ewart Farvis

The blind approach system had been developed by the Lorenz Company in Berlin long before the outbreak of war, and it had been installed at many airfields throughout the world. The system used modulated radio beams from a transmitter located at the end of the runway, such that if an aircraft were to the right of the approach path it received a series of dashes, whereas if it were to the left it received dots. The dots and dashes were synchronised, so that directly on the correct flight path they merged in an equisignal zone to form a continuous tone. Messages decrypted by the Bletchley Park codebreakers suggested that the Luftwaffe might be using a modified version of this popular commercial system in reverse, in order to guide their bombers to targets in Britain. This was confirmed when exploratory flights by an interception group led by Farvis located two radio beams from Kleve and Stollberg that intersected over the Rolls-Royce factory at Derby, which made Merlin engines for Spitfires and Hurricanes.

TRE soon developed countermeasures for this radio navigation system, which was called *Knickebein* ('Crooked leg') because of the 165° angle of its dual-beam transmitter antenna. When British jamming eventually revealed that the system was well understood by the RAF, many German bomber pilots preferred to keep out of the beam since they feared (mistakenly) that night fighters might be waiting for them all along the route to their target. By the autumn of 1940, raiders no longer considered *Knickebein* usable enough for target identification, although it was several months before the young German pilots plucked up the courage to tell Göring that the system was useless. However, the enemy had other shrewd tactics waiting in the wings.

X-Gerät

On 6 November 1940, a raiding He 111 bomber that had suffered compass failure over England tried to return to its base in occupied France by using a radio beacon at Saint-Malo. However, the beacon was being jammed by the RAF, so the crew became disorientated and instead of landing in Brittany the plane ran out of fuel and crash landed just offshore from the beach at West Bay in Dorset. British Army soldiers waded into the shallows and secured a rope around the fuselage, but then the Royal Navy arrived and claimed that because the plane was in the sea it was theirs to salvage. When the sailors towed it into deeper water to secure it to a ship, the rope parted, and the plane sank to the bottom!

In spite of this incident, the waterlogged radio equipment on board the aircraft was recovered and sent to RAE Farnborough, where it was found to include a new type of bombing radio navigation aid called *X-Gerät*. This system was considerably more sophisticated than *Knickebein*, having both coarse and fine director beams and 20 operating frequencies in the higher frequency range 65–77 MHz. The 0.05° fine director beam was so narrow that, in calculating its bearing, 5-figure log tables had to be used to take account of the fact that the earth isn't a perfect sphere but is slightly flattened near the poles. The *X-Gerät* system also laid three very precise crossbeams across the director beam prior to the target, which allowed the aircraft's ground speed to be determined and the bomb release point to be computed by a special 'bombing-clock' mechanism on board the plane.

Since the *X-Gerät* system required special equipment and trained aircrew operators, it was fitted only to the bombers of an elite group of pathfinders called *Kampf Gruppe 100* (*KGr100*), whose task was to mark the target with hundreds of 1kg thermite incendiaries on which the main force would bomb visually. Fortunately *KGr100* was based at Vannes, far to the west of France and beyond the reach of secure German military landlines; so the unit had to use wireless for ground communications, allowing messages, including the operating frequencies, to be intercepted and decrypted at Bletchley Park before each raid.

Once the technical characteristics of *X-Gerät* were understood, TRE lost no time in deploying several 100 Watt jammer transmitters, but, due to an error in the measurement of the audio modulation frequency, they were ineffective during the devastating 10-hour raid on Coventry. The mistake was corrected before the raids on Birmingham five days later, when the *Luftwaffe* bombers were partially disrupted and dispersed. By April 1941, the RAF had enough jammers to disrupt all the *X-Gerät* director and crossbeam frequencies and no other inland British city was to suffer such highly concentrated damage. In spite of at least eight attacks on the Rolls-Royce works at Derby during WW2, only a single bomb actually hit a factory building.

Except on moonless or cloudy nights, no radio aids were required to find the sprawling metropolis of London. But specific industrial assets in the city could not be targeted accurately without the help of reliable radio beams and the enemy bomb loads were scattered over almost 100 boroughs. Although no longer used by raiding bombers, the *X-Gerät* transmitters were kept functioning as decoys until they were finally dismantled in November 1942.

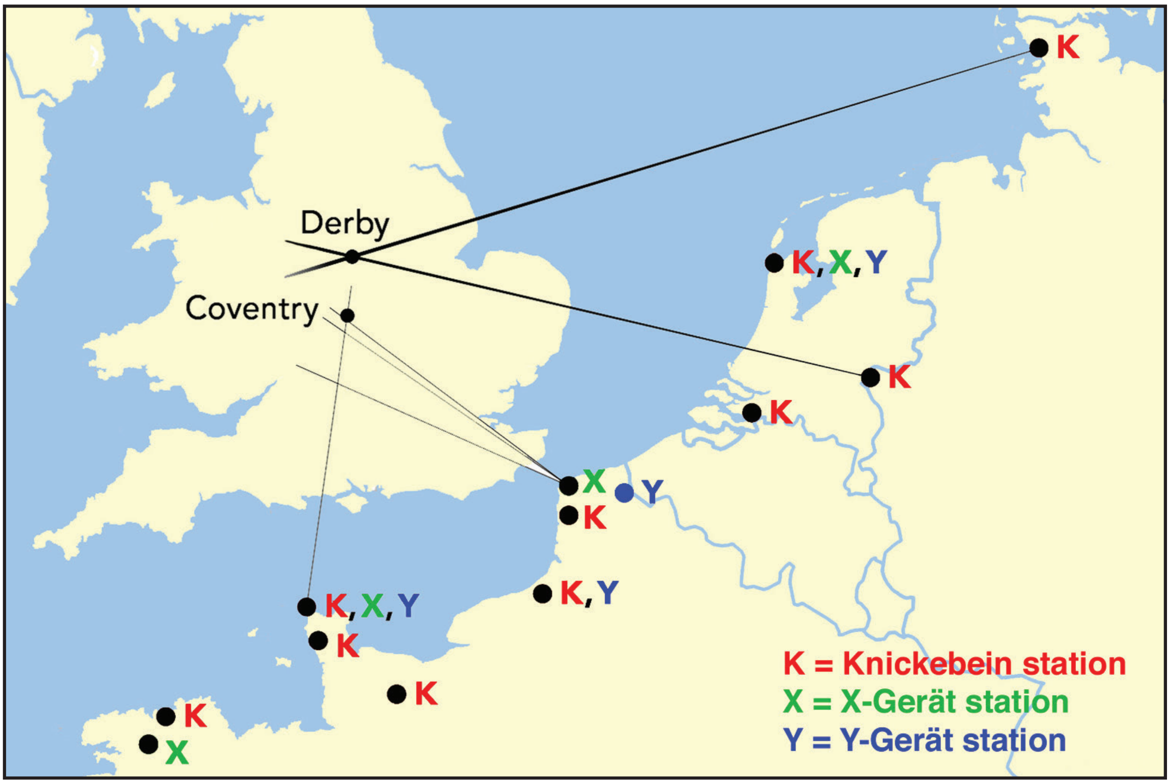
Y-Gerät

As early as mid-1940, when the existence of the *Knickebein* beams was confirmed, Enigma decrypts from Bletchley Park included mention of what appeared to be another system code-named 'Wotan'. Since this is the name of a Germanic God with only one eye, it was thought that it might refer to a new navigation aid that used only a single beam. It turned out that this reasoning was wrong, but the conclusion was perfectly correct. Monitoring stations began to report beam signals between 42.1 and 47.9 MHz that had different characteristics, with alternate right and left signals of equal duration transmitted at a high rate, for they were decoded in the aircraft electronically rather than aurally. The bearing analyser was coupled to the modified He 111 autopilot by an automatic flight control system that was much ahead of its time.

This more advanced *'Y-Gerät'* system achieved very accurate slant ranging by transmitting a tone-modulated carrier to a transponder in the aircraft on one frequency, and comparing the phase with the return signal carrying the same modulation sent back from the aircraft on a different one. The range measurement was made by the ground controller, who used a version of the *X-Gerät* stop-clock to determine when to order the aircraft to release its bombs. Since the system was more complex and could only operate with five aircraft at a time, planes equipped with *Y-Gerät* were formed into a specialised pathfinder group (Group III of *KG26*) that led the main bomber stream.

Alexandra Palace

Group III/*KG26* pilots made the error of practising using *Y-Gerät* for many weeks before trying it on a major bombing raid. So Farvis had time to analyse the signals and devise a subtle countermeasure that was ready for action on the very first night that the system was used for a large-scale attack on Britain. In the traditional British spirit of improvisation, he borrowed the powerful BBC TV transmitter at Alexandra Palace, which operated in the same frequency band and had been shut down at the outbreak of war lest it be used by the *Luftwaffe* to home on London. He set up an EMI TV receiver at the former outside broadcast relay station at Swains Lane in Highgate, with its bandwidth enlarged to accept both the ground control transmission on 42.5 MHz and the response from the pathfinder bomber on 46.9 MHz. From there, the modulation signal was sent by Post Office landline to Alexandra Palace, together with a subdivision of the carrier frequency that allowed the TV transmitter to zero beat with the ground transmission. At Swains Lane, Farvis sat listening to the German radio communications with his finger on a key that controlled Alexandra Palace remotely. At the critical moment, he sent the modulation back to the aircraft on 42.5 MHz, using a power that was sufficient to give a false range indication but not enough to arouse suspicion of jamming.

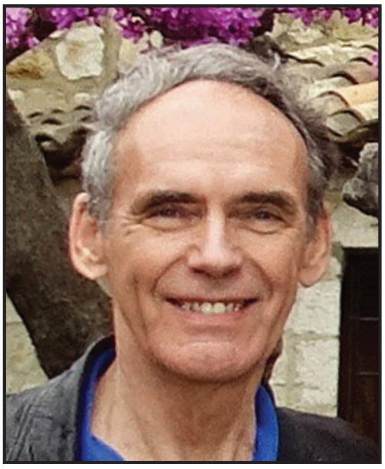


Locations of the radio beam transmitters in 1941

Alexandra Palace TV transmitter

Thirty years after the event, when Farvis finally felt free to reveal the ruse, he described the result as hilarious. Being fluent in German, he could follow the acrimonious radio dialogue between the bewildered young bomber aircrew and their ground controller as they argued about the cause of the perplexing behaviour of their instruments. The aircrew accused the ground station of sending bad signals, while the ground controller attributed the problems to airborne equipment failure, probably due to a loose wire. He even told the distraught operator to 'thump the box', which caused Farvis to remark that he was evidently a *real* radio man! The jamming was then repeated successfully with more pathfinders before the Luftwaffe abandoned the attack.

Bomber pilots eventually realised that *Y-Gerät* had been compromised from the first day that it was used, and they no longer put any faith in wireless navigation aids, making the accurate night bombing of inland targets very difficult. In one raid, the crews that thought they had bombed Nottingham dropped their weapons in open country 15 miles east of the city, killing two chickens with 230 high explosive bombs, one oil bomb, and five sticks of 36 incendiaries. In some raids, bombing was so scattered over the southern counties of England that it was impossible to deduce the intended target until it was revealed by the crews of downed bombers. Meanwhile, the tide of war began to turn. The experience of TRE proved invaluable when the Allies began to take the fight to the enemy, and, in the summer of 1942, the RAF used radio beams to bomb the Krupp arms factory in a precision night attack through ten-tenths cloud.



Dr Bruce Taylor

D-Day

At TRE, Farvis went on to analyse the signals of the German VHF IFF (Identification, Friend or Foe) system, allowing the team to develop the ‘Perfectos’ radio device that RAF night fighters used to trigger the transponders in enemy aircraft, to determine their positions without using radar. Following the deployment of Perfectos, many *Luftwaffe* crews flew with their IFF switched off and were shot down by their own flak.

In preparation for the D-Day landings, Farvis analysed the technical characteristics of the formidable menagerie of German radar systems that scanned the English Channel. This information allowed TRE to devise a sophisticated radar simulation of a huge armada of ships advancing towards the French coast at Cap d’Antifer, diverting the attention of the German forces away from the real force approaching the Normandy Coast. Prior to the operation, the spoof was tested by running a ghost ‘fleet’ towards captured German radars set up on cliffs overlooking the Firth of Forth. Just before the capitulation of Germany, Farvis was given the temporary rank of Squadron Leader (and a revolver) when he was flown to Munich to interrogate German engineers and scientists, and he had a fruitful discussion with the designer of *X-Gerät* and *Y-Gerät*, Johannes Plendl.

There can be no doubt that the secret radio work of Farvis and his TRE and RAF colleagues significantly changed the course of WW2 and saved thousands of lives. Without effective electronic countermeasures, there would have been many more instances like the destruction of Coventry. Concentrated pin-point bombing might well have destroyed the British aero-engine and Spitfire factories, altering the outcome of the war. In a light-hearted tribute at the end of the conflict Churchill wrote, 'You certainly did pull the crooked leg'.

Among many honours, Farvis was elected to a Fellowship of the Royal Society of Edinburgh in 1958, and he was appointed OBE in 1972 and CBE in 1978. He died on 12 October 2005 at the age of 93. In his memory, the Ewart Farvis Prize is awarded annually to an outstanding final year student of the BEng Honours programme in Electrical Engineering at Edinburgh University.

Images:

Page 286: AMES Type 2 Chain Home Low radar installation at Hopton-on-Sea, 1945, Imperial War Museum Collection, (public domain) **<https://www.iwm.org.uk/collections/item/object/205196698>**

Page 287: Prof Ewart Farvis, courtesy of the late Dr Colin Davidson.

Page 290, Upper: Locations of the Knickebein, X-Gerät and Y-Gerät beam transmitters in 1941, courtesy Bill Rankin **<http://www.afterthemap.info>**

Page 290, Lower: BBC transmitter antenna at Alexandra Palace, London, based on photo by Duncan Harris, (CC-BY-2.0) **<https://commons.wikimedia.org/wiki/File:Flickr_-_Duncan~_-_Alexandra_Palace.jpg>**

Page 291: Dr Bruce Taylor.

General Council Half-Yearly Meeting

The next General Council Half-Yearly Meeting will be held on

Saturday 6th February 2021 at 10.30am

The Principal, Professor Peter Mathieson, will present the Annual Report of the University. The meeting is open to all General Council members and will take place online via Microsoft Teams.

The format of the meeting will follow the usual timetable. The agenda and papers are in the winter edition of Billet.

For further information please visit

<https://www.general-council.ed.ac.uk/newsandevents/half-yearly-meeting-6-february-2021>