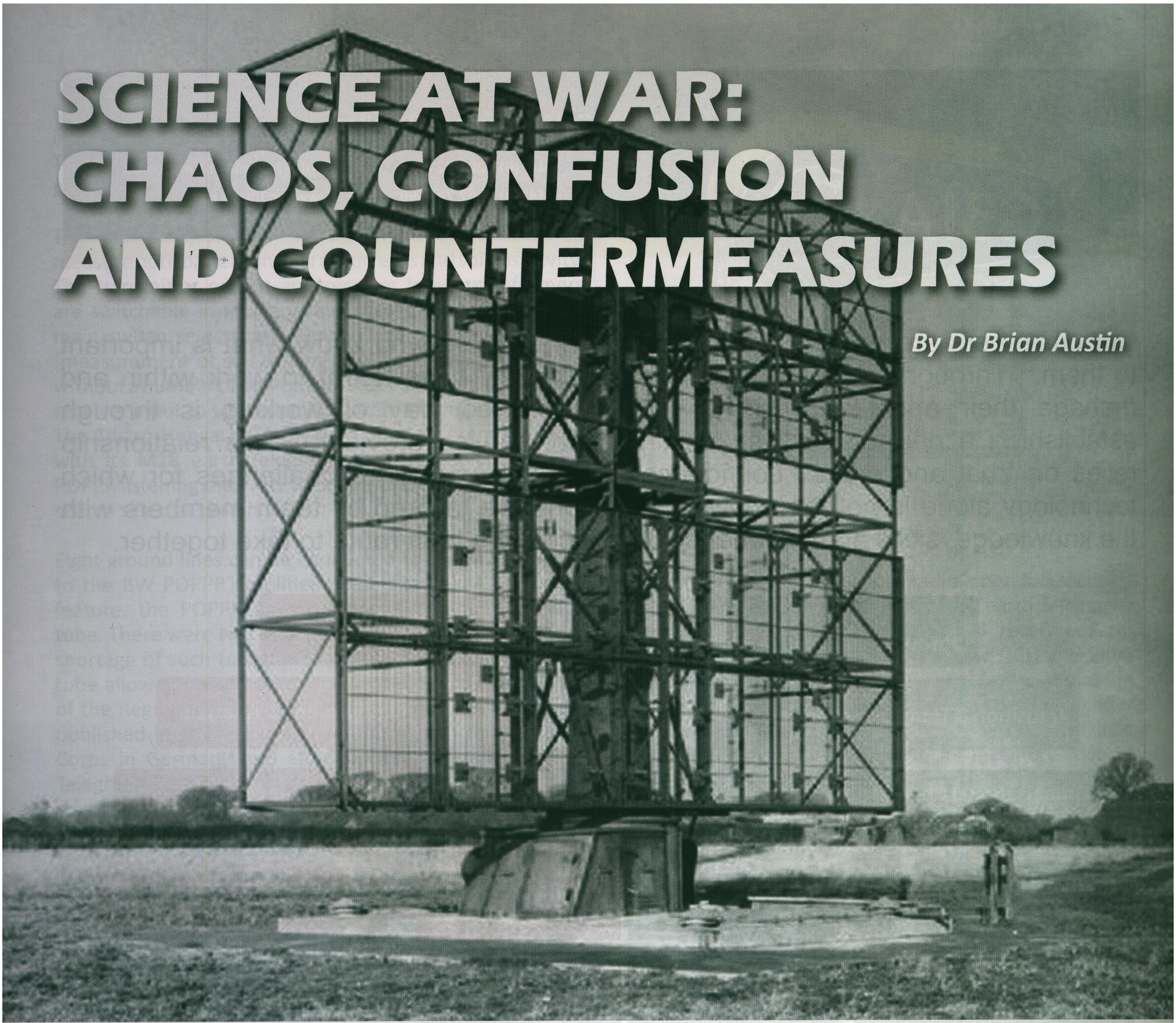
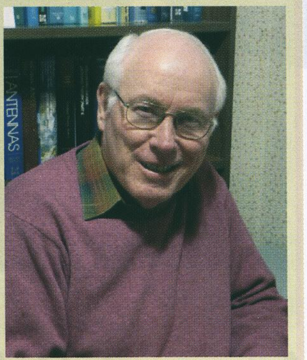


SCIENCE AT WAR: CHAOS, CONFUSION AND COUNTERMEASURES

By Dr Brian Austin



Dr Brian Austin is a retired senior lecturer of the Department of Electrical Engineering and Electronics of the University of Liverpool. Born and educated in Johannesburg, he graduated from the University of Witswatersrand in 1969 and spent the next ten years in industry, working mainly on radio communications underground in mines.

He returned to academic life, first at his alma mater, and then, after emigrating with his family to the United Kingdom at the University of Liverpool. He did national service in the South African Corps of Signals and served for nine years in the Citizen Force (TA equivalent), retiring in the rank of Major.

The part played by the Army Operational Research Group (AORG) during the Second World War has, perhaps, not received the attention from historians that it deserves. On its formation, in August 1941, as the Operational Research Group of what was called the Air Defence Research and Development Establishment (ADRDE), it expanded rapidly such that, by February 1943, it had outgrown its parent organisation and became the AORG, separate and self-sufficient. Its Superintendent was Brigadier Basil Schonland OBE (mil) FRS, a physicist from South Africa who was well-known in Cambridge, having studied there under Lord Rutherford both before and after the First World War.

During that first encounter with the Germans, Schonland had served in the Royal Engineer Signal Service, the forerunner of the Royal Corps of Signals where, after living dangerously in the Wireless Squadron of the Cavalry Corps, he became a Wireless Research Officer at the GHQ Central Wireless School in Montreux. Following the armistice and his subsequent discharge from the Army in January 1919, Schonland returned to Cambridge to continue his research in nuclear physics but not before the Army tried to persuade him to stay on as Chief Instructor in Wireless [1].


BRIGADIER B.J.F. SCHONLAND C.B.E. F.R.S.

Back in uniform again in September 1939 following South Africa's declaration of war against Germany, Schonland led a small team of engineers and scientists, based at the University of the Witwatersrand in Johannesburg, who developed a radar (or RDF as it was known then) set within three months of the outbreak of war. This remarkable feat was made possible by the top-secret briefing given to scientists from Britain's Dominions (Australia, Canada, New Zealand and South Africa) that had taken place at Bawdsey Manor, the home of British radar near Ipswich, earlier that year. The South African-designed radars soon went into service in East Africa, in the Sinai to provide cover for the Suez Canal, and all around South Africa's coastline. Schonland soon found himself back in England where his services were required on the very much bigger stage.

The Army's Radars

The first and most important application of radar in the British Army was in anti-aircraft (AA) artillery and the first radar set to assume that role was the GL1, a gun-laying radar. Its purpose was to provide early warning of approaching aircraft, and it was capable of little else at that stage. However, the AORG scientists attached to the gun batteries soon improved things by means of careful calibration against known references provided by large wire- mesh ground screens as well as what was called the Bedford height-finding attachment to the radar. A measure of the success of any AA battery was the number of 'rounds per bird' required to bring down an enemy aircraft. That figure decreased four-fold within a year of the installation of the radars at the gun sites. Another great step forward was made in 1941 when searchlight control radar was introduced. Known as SLC, or more popularly as 'Elsie', this innovative development saw the installation of a complete radar set, including an array of six Yagi antennas, on the searchlight. Though met with some scepticism by the occasional battery commander who informed all and sundry that he'd not joined the army to become an electrician, it was fortunate that the man in command, General 'Tim' Pile, saw all the advantages of applying the scientific method to soldiering. With Pile's energetic support 'Elsie' soon became an indispensable component within the AA armoury.

Seaward defence was also Pile's responsibility and coast watching or coastal defence (CD) radars for plotting the approach of surface vessels were set up in 1940 along the south-east coast of England. They were known as CD/CHL sets and were an offshoot of the famous Chain Home radars, originally developed before the outbreak of war and which effectively saved the nation by providing early warning of the massed air raids by the Luftwaffe during what became known as the Battle of Britain. One shortcoming of the low-frequency Chain Home (CH) radar was its inability to detect aircraft flying at low altitudes. To overcome this, a radar operating at a much higher frequency of 200 MHz was designed and it became the Chain Home Low or CHL. Adapting the CHL specifically as a coastal defence radar led to the CD/CHL set. A further significant development followed soon afterwards when the first 10cm wavelength radar, the CD No 1 Mk IV, an adaptation of the Royal Navy's Type 271 radar, went into service near Dover in the autumn of 1941 and then, subsequently, at three other sites nearby. The considerably higher target resolution provided by the much shorter wavelength, as well as the increased range, soon made this microwave radar a most effective piece of equipment. Small vessels could be tracked to a distance of 70km, from a sufficiently elevated radar site, while large ships could even be seen leaving Boulogne. It was the AORG that provided the technically skilled manpower that husbanded those various radars as they provided the crucial early-warning and target-tracking for the guns defending British shores.

The Channel Dash

By late 1941 the Germans had begun to jam British radars and it soon became a matter of much concern. Things really came to a head in February 1942. On the 12th February, three German naval vessels, the battlecruisers Scharnhorst and Gneisenau and the heavy cruiser Prinz Eugen left the French port of Brest where they had been holed up for many months following an extended period of commerce raiding in the Atlantic. Their destination was their home ports in Germany. The whole operation was a brilliant piece of naval manoeuvre, executed with great precision and involving seamanship of the highest order. All three ships, though damaged en route, escaped through the Channel, and the narrow Straits of Dover, to considerable British consternation and calls for action to be taken at the highest level. To many in the public, when the news broke, and within the lower echelons of the military this episode bore all the hallmarks of incompetence with some even suggesting it was Britain's equivalent of the attack on Pearl Harbour [2].

Such a breakout was not unexpected, however, because it was common knowledge that the three German capital ships had sought refuge in Brest where they had been

subject to considerable (though mainly unsuccessful) bombardment, and reconnaissance, by the RAF. However, when it came, its sheer audacity took British defences completely by surprise because it was always believed that Admiral Ciliax would try to take his ships through the Straits of Dover under cover of darkness. But he chose to do so in broad daylight despite being well within range of the shore batteries and, one must presume, of British radars. The Germans knew this too and so they sought to neutralise those radars by means of very carefully-controlled jamming. The intensity of the jamming, at the 200 MHz frequency of those CD/CHL radars, was increased gradually over a period of many days prior to the breakout. The jamming transmitters were at Boulogne and Cap Griz-Nez and their emissions had certainly not gone unnoticed by some in England but the warnings which they issued were initially ignored. When eventually it was appreciated that this perceptibly increasing noise level was all part of a concerted attempt to disable the coastal radars – and thereby make it more feasible for those three German ships to make their dash through the Channel – it was too late. They were already on their way.

The Channel Dash and the concomitant jamming of British radars – the first occasion on which such concerted action had been used in warfare – set in motion a whole chain of events aimed specifically at developing radio-based countermeasures to at least diminish, if not to thwart, such threats in future [3]. To add to the confusion then rampant within the higher commands of all three services was the fact that the 10cm radars, of which the Germans had no knowledge, had not been jammed. The radar near Hastings had detected the three large and rapidly moving ships but delays in passing that information to the coastal batteries afforded them no more than twenty minutes to register and fire their guns before the targets passed out of range.

Scharnhorst

The escape of the three prized ships and the bungling it revealed in many quarters was regarded as a débâcle within Whitehall and reaction to it followed swiftly. At a stormy Inter-Service meeting responsibility for the investigation of all forms of radio (and hence radar) jamming now passed from the Air Ministry, whose responsibility it had been, to the War Office. Since there was no suitable organisation within the Army to undertake this task, it fell to Schonland's AORG to set up what immediately became known as the J watch with a mobile laboratory and suitable radio-equipped J vans. In view of these recent events and the undoubted sophistication of the German's jamming techniques, the great concern was that they might soon deploy airborne jammers against which there were, apparently, no available countermeasures.

Cometh the Hour …

Schonland appointed J S Hey to take charge of the J watch. Stanley Hey was a young physicist whose knowledge of radio, so he claimed, was minimal when he joined the AORG. However, a six-week course run by J A Ratcliffe, one of Cambridge's most inspired teachers and researchers, at the Army Radar School in Petersham, soon gave Hey sufficient background to become a most useful member of Schonland's circus, a name inherited from its forerunner under the Nobel-laureate-to-be, Patrick Blackett. As happens so often, especially in scientific research, serendipity had its part to play.

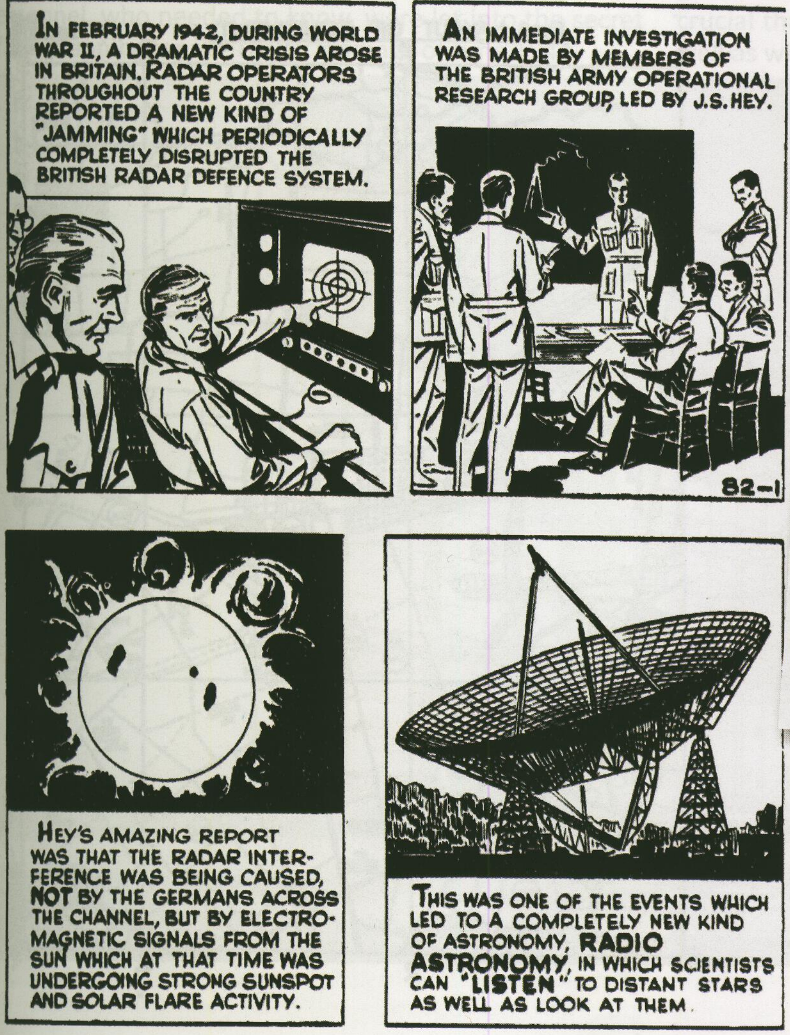
On 27 and 28 February 1942, just two weeks after the escape of the German battleships, various British coastal radar sites reported jamming so intense as to make normal radar observation impossible. These were the gun-laying radars operating on wavelengths between 4 and 8m (75 to 37.5 MHz), and the source of the jamming was moving! Was this the first indication that the enemy was now deploying an airborne jammer? But no air raids followed. Even so, alarm was widespread among the military, and Hey's task of identifying the source was given considerable impetus.

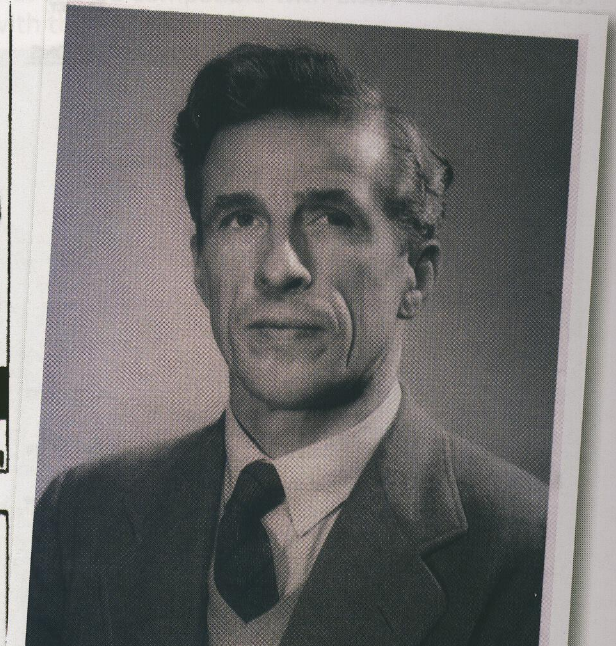
From the systematic reports he'd received from the radar sites it was apparent that the affected radars had all been 'looking' in the direction of the Sun when the interference was most intense, and by noting the different antenna headings over a period of time it was clear to Hey that the Sun, as its position changed in the sky, was most likely the source of this intense radiation. Hey immediately telephoned the Royal Observatory and enquired whether anything unusual was happening on the Sun at that time. He was informed that a very large sunspot group was in transit across the solar disc and it was, in fact, situated on the solar meridian – the most favourable position for radiation toward the earth – on 28 February when the interference was at its peak.

Hey immediately wrote a report which he presented to Schonland. Early in his AORG career Hey had discovered that his style of report-writing left much to be desired when he was summoned by Schonland and told that there was considerable room for improvement. 'Remember, Hey', said Schonland, 'we are writing for soldiers not scientists, so clarity of both thought and presentation is crucial'. Hey took that to heart and soon thereafter he received his Superintendent's ready accolade at the improvement. Having read the latest document Schonland again summoned Hey but this time he congratulated him. He also asked whether Hey was familiar with the work of one Karl Jansky from the Bell Telephone Laboratories near New York who, in 1932, had reported that the galaxy was a source of considerable noise within the radio frequency spectrum. Hey was not. He immediately visited the library at the Science Museum where he was able to read Jansky's papers as well as those by another American, Grote Reber, on the radiation from outer space which, to the untrained ear, sounded just like noise. Taken together, all the evidence now pointed to the Sun as the source of intense radiation, not just at optical and infra-red wavelengths but also within the range of frequencies on which many British radars were presently operating. Jamming it was but there was no malevolent intent behind it.

Radio Astronomy

Hey's announcement that the Sun was a powerful source of radio waves, though causing considerable relief in military circles, was greeted with a degree of scepticism by some of his colleagues at the AORG (though not by its Superintendent), and also by others within the much higher echelons of the physics establishment. There, as Hey subsequently put it, it seemed to them to be 'almost an effrontery for a comparative novice in the field to be presenting a paper on an energetic solar radio phenomenon' [4].





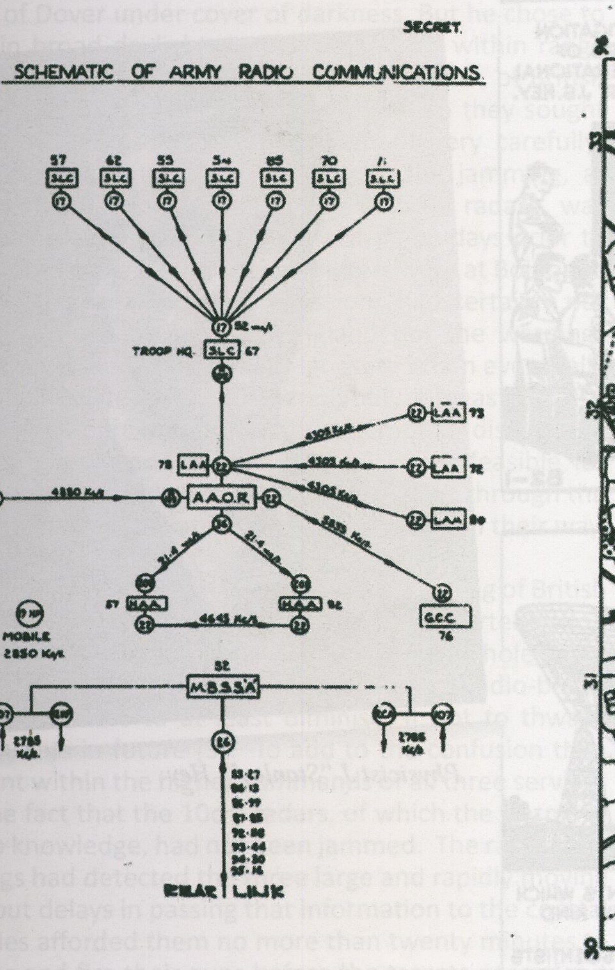
Physicist J "Stanley" Hey

One of those who fell into that category, when he first heard of Hey's discovery, was none other than Sir Edward Appleton, soon to be awarded the Nobel Prize for Physics for his discovery of the ionosphere. But Appleton rapidly became a convert and more than that he used his stature as one of the country's pre-eminent scientists to 'muscle in' on Hey's immediate post-war research into the solar radiation phenomenon. Appleton, by now Principal of the University of Edinburgh, saw an opportunity for some collaboration with Hey but his actual motive become clearer when he was rather quicker off the mark in publishing the first British paper, in the open literature, on the subject of radio emissions from the Sun. Hey, ever the gentleman, said nothing but may well have raised an eyebrow. His first paper on the subject followed Appleton's in the very next issue of Nature [5].

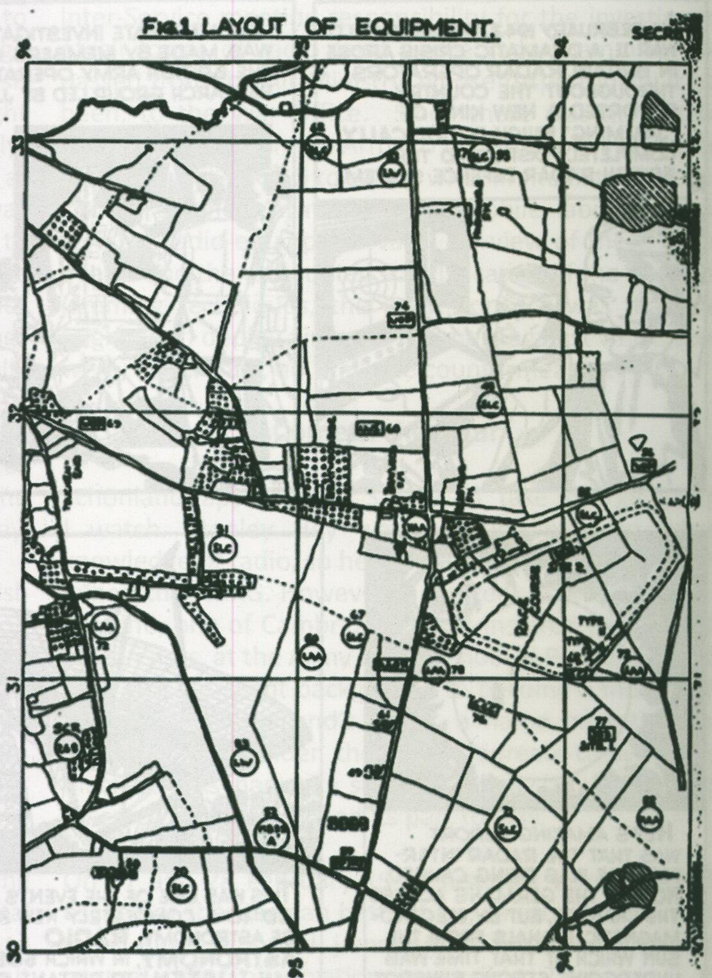
And so it was that a wartime discovery, of the very greatest importance to the Allied war effort, actually ushered in a completely new area of scientific research. Hitherto, observational astronomy had been almost exclusively within the domain of those using optical telescopes. Following Hey's work in early 1942 at the AORG, radio astronomy soon became a scientific stripling and, very soon, it established itself as a new branch of the queen of the sciences. Interestingly enough, at least three other pioneers in the field of radio astronomy had been heavily involved in wartime radar. Sir Bernard Lovell at Jodrell Bank was one of the pioneers in the development of H2S, the radar that revolutionised the art of bombing by presenting the bomb aimer with a picture on a cathode ray tube of the ground beneath the aircraft. What had until then been almost a random process of hitting the target, especially at night or when in dense cloud, became a precision technique when practised by RAF and USAAF aircrews during the closing stages of the war.

One of Lovell's closest collaborators at Jodrell bank was Robert Hanbury Brown, whose involvement with radar went back even further than that of Lovell. Hanbury Brown worked at Bawdsey Manor under Sir Robert Watson-Watt, the father of British radar, when radar was in its infancy and everything they did was at the very edge of scientific discovery.

Two other famous radio astronomers, Sir Martin Ryle and Sir Anthony Hewish, who shared the Nobel Prize for Physics in 1974, teamed up at Cambridge after their wartime service at the Telecommunications Research Establishment where they had worked on radar countermeasures. Individually they went on to make remarkable discoveries, most notably the invention of the technique of aperture synthesis and the identification of the first pulsars.



Equipment layout for Exercise Feeler, December 1943.



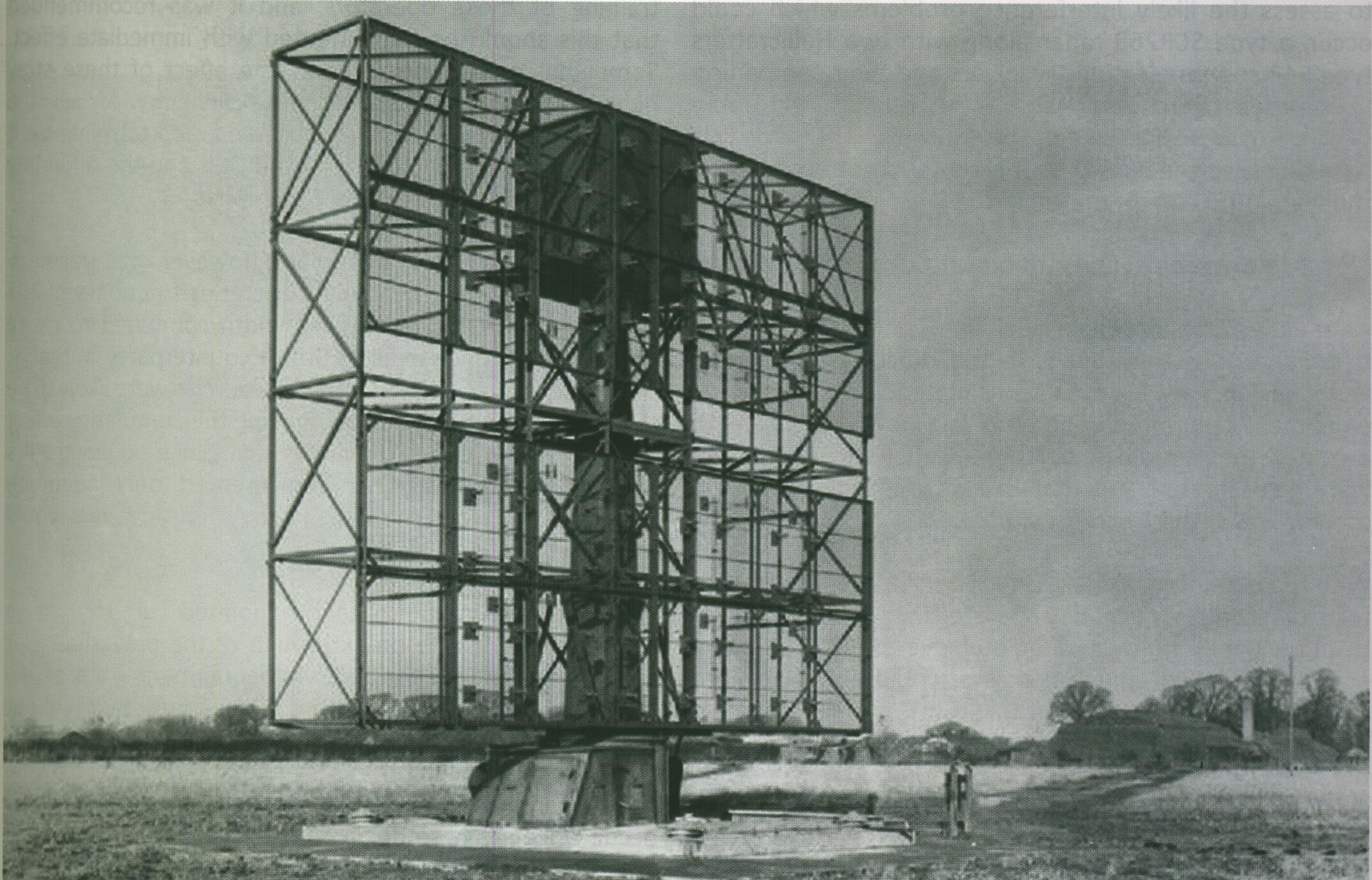
On the Beach

After reading the report on Operation Torch, the joint British and American landing on the beaches of French North Africa in early November 1942, Schonland made contact with Brigadier Sayer, who was soon to become Director of Radar at the War Office. Schonland was concerned that the landing of tens of thousands of men and their equipment on three widely separated beaches went far from smoothly and yet it was generally unopposed by the enemy. Command and control were dogged, in the words of the Chief of the Imperial General Staff, Field Marshal Alanbrooke, by 'a certain confusion – even chaos'.

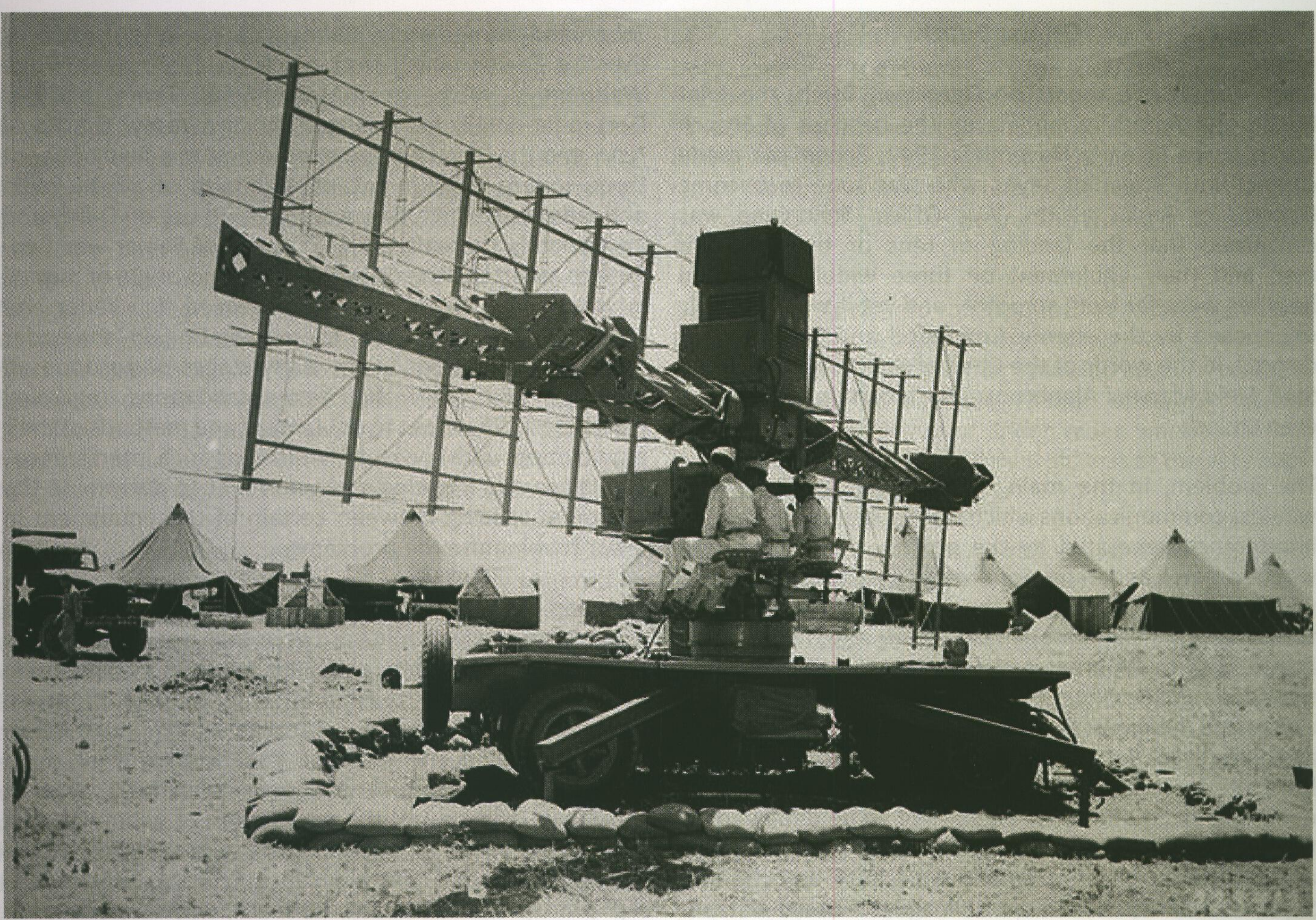
The problem, in the main, was a near breakdown in wireless communications which was caused by the mutual interference generated by the proliferation of different wireless sets, and numerous defensive radar systems, which had been set up on the beachhead immediately the landings near Casablanca, Oran and Algiers had begun. How much greater would be the problems when the invasion of Northwest Europe with their vastly greater armies and their masses of equipment began? Schonland's advice to Sayer was that a study should be made of the likely interference problems that might exist between the numerous radio and radar equipment to be deployed on the beaches of Normandy. The fact that Schonland was aware of those plans came about because both he and Sayer, as well as their radar colleagues Robert-Watson-Watt and Professor John Cockcroft, had recently been 'bigoted'. This was the process whereby certain senior personnel, who needed to know, were let into the secret of the planning for the D-Day landings of June 1944.

Schonland immediately planned an exercise, known as Exercise Feeler, which took place on a site near White Waltham, a village near Maidenhead. There, early in December 1943, he arranged for the Army, the Royal Navy and the Royal Air Force to deploy, in a field of about three square miles in extent, examples of all the radio and radar sets which they were likely to use on D-Day and immediately thereafter. The purpose of Feeler was two-fold: to ascertain 'the degree, nature and origin of mutual interference ... likely to be experienced if ... radar and communications equipments are operating on land under congested conditions in the early stages of an opposed landing'; and to 'make recommendations regarding possible modifications to equipment and methods of their employment with a view to minimising such interference'. The latter also included a requirement to determine the minimum spacing between certain of the equipment in order to minimise the problems.

Between them, the three services would be deploying a wide range of electronic hardware that was by no means necessarily compatible, one with another. For example, there was a need to establish the most appropriate layout of the GCI (ground- controlled interception) radars of the RAF and the four SLC radars, plus their radio communications, whose purpose, collectively, was to coordinate and control the interdiction of enemy aircraft over the beachhead. In addition a radar known as the Baby Maggie, a fire-control radar using the so-called 'mag-slip' principle of automatic feedback, was very similar in design to the SLC (hence Elsie and Maggie), and operated in the same 200 MHz frequency band. It was therefore crucial that she be compatible with Elsie, the GCI sets as well as with the RAF radio sets.



SCR 268 Radar.



GCI Radar.

To further complicate the matter, the American forces, operating on the British flank, would be deploying their full array of radar and communications equipment. In order to assess the likely interference problems which could occur, a type SCR268 radar along with two Hallicrafters type 543 communications receivers and their companion transmitters were deployed at the furthest extremity of the Ex. Feeler test site. The '268 was the very first American-designed radar to become operational during the war and it, too, operated in the 200 MHz band.

Harmonics, Overload and Congestion

After eleven days of tests a clear set of findings had begun to emerge. As they put it in the official AORG report issued in February 1944: '... it was quite feasible to use the equipment under the conditions laid down for the trial, provided that certain minor modifications to equipment were incorporated and that in a few specific cases the spacing was slightly increased' [6] .

With the exception of the 10cm GL MkIIIB all British radars to be deployed in Normandy operated in the band from 204 to 212 MHz. If one radar should inadvertently 'illuminate' another, so-called unlocked pulses would appear on the cathode ray tube in addition to those from the intended target. If the radar frequencies were sufficiently different the effects were not unduly serious as long as the respective pulse repetition frequencies (PRF) were not synchronised. Fitting anti-jitter filters to the all affected receivers, and separating the radars by around 800 yards usually solved it. A more effective solution proposed was to make the PRF adjustable and under the control of the radar operator allowing him to take corrective measures whenever necessary. Naturally such a change had an impact on the training of those operators, and it was recommended that this should be implemented with immediate effect. Somewhat more worrying was the effect of these stray pulses on the GCI's height-finding capability. An average error of 1300 feet had been observed, and to minimise it required a separation between the GCIs and the offending SLC or Baby Maggie of some 1 to 2 miles.

By far the most serious problem, however, was traced to the American SCR268 radar. Its operating frequency of 201 MHz, high PRF and long pulse width combined to cause severe interference to all its British counterparts. In reality, more than just the one used in this exercise were likely to be deployed on the British flank making the cumulative effect of this interference of much concern. Since no electronics solution could easily be implemented only adequate separation between the British and American radars would mitigate the effect.

Whenever a radar antenna pointed directly at a communications site breakthrough of the powerful radar signals desensitized the receiving equipment – a problem known as blocking. In addition, it was found that without exception all the radars produced spurious emissions at discrete HF frequencies and should any of these coincide with a communications channel serious disruption could occur. Once again, setting a minimum distance between all the radar and radio equipment usually solved the problem. The only exception to this was the Army's No. 26 multi-channel communication equipment which operated in the band from 80 to 95 MHz while providing six simultaneous speech channels from its 100W transmitter. It was discovered that the receiver was easily overwhelmed whenever any radar or other communications systems were operating nearby. This total lack of immunity to strong unwanted signals gave a clue as to the cause of the problem: spurious coupling was occurring across the input transformer of the first amplifier stage of the receiver and the fitting of a suitable electrostatic shield between those transformer windings took care of it. Immediate implementation of that solution followed.

In all, Exercise Feeler showed that the four different types of radar equipment to be deployed by the Army on the beaches of Normandy, along with the three versions (GCI, and types 11 and 13) in use by the RAF as well as the type 277 to be deployed by the Royal Navy could now be made more or less compatible one with another. Fortunately, the decision to include the American SCR268 radar was fortuitous because it led to the discovery of the possibilities of severe interference from that source. Ex Feeler showed what countermeasures were necessary to render it compatible too.

The Outcome

Operation Overlord, as history has recorded, was a remarkably successful operation given the huge numbers of men and equipment involved, plus the near logistic miracle it took to get them from their starting points around England's southern coast to the beaches of Normandy. The fact that the Allies had almost complete command of the skies above the beachhead undoubtedly played a major part in this, but at least one factor in ensuring that that was the case was the success of Exercise Feeler. Radar and its accompanying radio communications worked as planned. This, and the decoy measures provided by Operations Taxable and Glimmer, which by dint of exceptional use of electronic countermeasures and the flying skill of the RAF, confounded the enemy and convinced him that the invasion forces would arrive on the continent of Europe by way of the Straits of Dover. Meanwhile, they came by a different (and much longer route) more than a hundred miles away.

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GLIII Radar.