THE DEVELOPMENT OF RADAR IN NEW ZEALAND IN WORLD WAR II

In the 1990s radar as an essential aid to navigation in the air and on the sea is so commonplace that it is difficult to realise that in the mid 1930s, less than sixty years ago, it was a completely new technique that was being hastily developed in the greatest secrecy by the chief combatants of World War II – Great Britain, Germany, the United States, Japan, France, Italy and the Soviet Union. Although the concept of detecting the presence of an aircraft or ship through measuring the delay of a radio signal reflected from it back to the position of the transmitter was not new, it was only in the mid thirties that research and development began in these countries in earnest. Considering the effort that was being put in the development of radar in the three or four years immediately prior to the outbreak of World War II, it is amusing to realise that a German inventor had been granted a patent covering the basic idea of radar in 1904[1], and that Marconi in a speech to the American Institute of Engineers in 1922 said "... I have noticed the effect of reflections of these (radio) waves by metallic objects miles away ... it should be possible to design apparatus by means of which a ship could radiate ... in any desired direction, which rays, if coming across ... another ship, would be reflected back to a receiver screened from the local transmitter ... and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather.[2]" The Americans Breit and Tuve in 1926 first used pulse radio transmissions to determine the source of a distant object, in this case the ionosphere[3], while in 1928 a patent for "..... methods and means for determining the positions, directions and distances of objects by wireless waves, applicable to navigation and for the location of dangerous objects or enemy craft" had been granted to Salmon and Alder of the Royal Naval Signal School in England[4]. Had these ideas been followed up at the time, the history of radar development would have been vastly different from what actually occurred.

It is not the purpose of this article to say anything about the development of radar in different countries apart from those that had a direct effect on the work in New Zealand, as the topic has been covered in numerous publications[5,6]. Not surprisingly, since New Zealand was a member of the British Commonwealth, it was from Great Britain that the initial information on radar development came. It arose in the following way:

Early in 1939 when it was recognised that war was imminent, the British Secretary of State for Air asked that a physicist be sent to England (along with other Commonwealth representatives) for training "in an entirely new scientific technique of a defence nature". The reasoning behind this was that Great Britain in 1939 was putting all its effort into building radar for its own needs, so it would be necessary for Commonwealth countries to devise their own, at least initially, and each build up a team who could in due course assist in the introduction of radar systems as and when they became available. Thus did one physicist in each of a number of Commonwealth countries learn the basics of radar as it had been developed in Great Britain up to the time of the outbreak of World War II. The New Zealand representative was Dr. (later Sir) Ernest Marsden (the Marsden who with Geiger performed the crucial experiments in Rutherford's laboratory at Manchester that led to the discovery of atomic structure).

New Zealand was lucky to have a person of the calibre of Dr. Marsden to send to Great Britain. As head of the NZ Department of Scientific and Industrial Research (DSIR) he had the authority to establish a research and development programme immediately on his return from overseas. In England he was able to secure a number of critical components, virtually unobtainable in New Zealand, such as coaxial cable, oscilloscopes, a Pye television receiver (actually two), and an incomplete 1.5 metre ASV (Air to Surface Vessel) radar, which had just been developed for the British Royal Air Force. He was able to establish a permanent arrangement in England for a continuous flow of highly classified technical data on radar developments and operations, and a fund which ensured that a supply of components otherwise unobtainable in New Zealand were available (when they could be spared) for radar development.

New Zealand, then as now, was a small country in a vast ocean, isolated from the rest of the world, with a long coastline. It was clear that the chief danger would be from enemy submarines and raiders, and possibly warships. The need was therefore to detect surface vessels from land, sea and air, and provide gunnery and searchlight control for the cruisers of the New Zealand Navy and coastal batteries guarding the main ports. By early 1940 developments were under way for all these purposes.

The highly secret programme was begun in two locations. One was the Radio Section of the NZ Post Office (in Wellington), at that time the organization in the Civil Service most advanced in electronic techniques. Two Post Office engineers were allocated part time to the work, and two or three technicians. The other location was a high-security laboratory in Canterbury University, Christchurch, under physics professor F W G White (later Sir Frederick White, head of the Australian CSIRO). To both these laboratories DSIR scientists were seconded in slowly increasing numbers – initially D M Hall in Christchurch and C. N. M. Watson-Munro (later Director of the Australian Atomic Energy Commission and professor of plasma physics, University of Sydney) in Wellington. The two teams were given different objectives by Dr. Marsden. That in Christchurch was given a self-squegging transmitter, an IF strip from a Pye television receiver and some high frequency valves, and was asked to develop ship-borne radar for the detection of both aircraft and ships, and to direct naval gunfire. The

Wellington team were to develop radar sets for coastal locations to detect shipping, an airborne set for the same purpose (ASV), and to provide precision radar for the fire direction of the 150 mm batteries guarding New Zealand's main ports.

Also in late 1939 it was arranged that a special one-year course in radio physics be established at the Universities of Auckland and Canterbury, open to recent physics graduates or those taking their final year in a BSc course. (The author of this article was one of the 1940 class at Canterbury.) By this means the number of physicists and engineers actively working on radar in Wellington had risen from three in January to nine in December 1940, although the Christchurch group remained at two physicists, an engineer and two technicians.

Both the teams in Wellington and Christchurch faced daunting technical problems in developing novel techniques far from the help of their more advanced colleagues overseas, and with minimal library back-up restricted to the small amount of information that Dr. Marsden had been able to bring with him from Great Britain, and the trickle of new information that spasmodically appeared.

However, in spite of these disadvantages and the small number of people involved, the work achieved in that first year was remarkable. The first radar echoes were seen by Watson-Munro from the top floor of the Wellington Post Office building at the end of 1939. The receiver used an IF strip from a Pye television receiver and the transmitter was a self-squegging oscillator on 183 MHz using a pair of RCA 834 valves in push-pull with separate receiving and transmitting antennas each consisting of a centre-fed dipole and reflector. The transmitter produced 2 microsecond pulses at about 1 kW peak power, and was the basis of all the land-based CW (Coast Watching) and gunnery control CD (Coast Defence) radars until around mid 1941 when the more powerful VT90 "micropup" tubes became available.

Between January and June 1940 the staff in Wellington had increased by four (E. R. Collins, later professor of physics at Auckland University, K. D. George, I. K. Walker, subsequently assistant Director-General of the NZ DSIR, and C. H. Vincent). The main effort was put into designing receivers, broadside antennas and displays for the various radar systems. The task was simplified by the fact that all of them except that for naval gunnery (see below) operated close to 200 MHz so only one design of transmitter and receiver, and antennas to some extent, served all needs. By the middle of 1940 a CW set was operating for the Navy at Auckland, an airborne ASV was under trial, and an experimental air and surface warning set was operating on the cruiser HMS Achilles. By the end of the year CD sets were operating for the Army at coastal batteries at Auckland and Wellington, three CW sets for the Navy on the approaches to Auckland and Lyttelton, and an experimental early warning and gunnery control set on HMS Achilles.

Further development and refinement of these early sets continued through 1941, but in the second half of that year there was a major change in administration. Whereas the DSIR staff had been primarily responsible for research and development, and the Post Office for construction of radar sets, the whole of the programme was now put under the control of DSIR. The Radio Development Laboratory (RDL) with Watson-Munro as director, was formed as a branch of DSIR to carry out the programme. Professor White had at this time been loaned (subsequently permanently) to Australia and his Christchurch unit was put under the control of RDL. Dr. O. O. Pulley (on loan from Australia for a year in exchange for Professor White) took over as director until October 1942 while Watson-Munro was in the USA (see below). In June 1944 Watson-Munro was replaced as director by I. D. Stevenson, who was in turn replaced by J. B. C. Taylor in September 1945 until RDL was wound up in 1946. Early in 1942 RDL moved from Post Office quarters to its own premises and staff members increased rapidly, reaching 100 of all ranks by the end of 1943, including 29 physicists and 11 engineers.

COAST WATCHING (CW)

The New Zealand Navy with responsibility for coast watching, required a number of simple radar sets, capable of being installed on remote hilltops (often without road access) and offshore islands, and powered by small generators. This requirement resulted in the set shown in Figure 1A. As mentioned above, the transmitter (Figure 1B) consisted of a squegging oscillator using a pair of RCA 834 tubes in push-pull and generating a 2 microsecond pulse of around 1 kW.

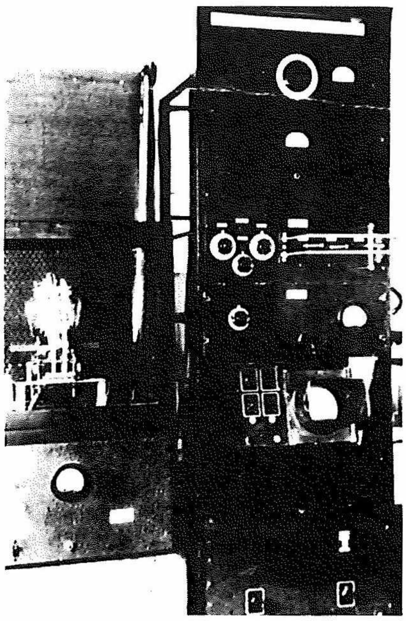


Fig. 1A. CW Radar — transmitter on left, receiver and display on right.

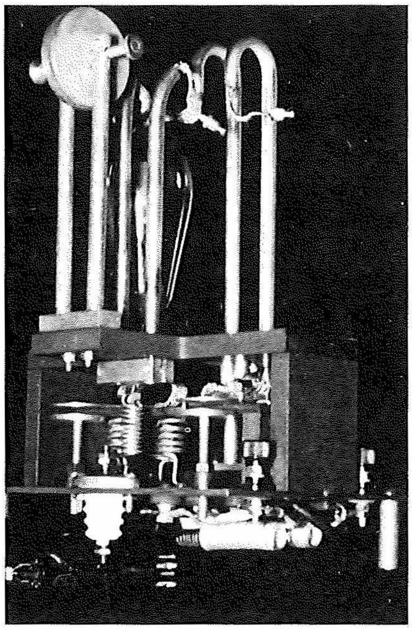


Fig. 1B. Early CW transmitter with one RCA 834 tube removed.

The pulse triggered a simple time base on a 15 cm CRT, and echoes deflected the spot at right angles to the trace. The transmitter pulse also kicked into operation a critically damped oscillator on 82 kHz, from which after amplification and differentiation range "pips" were provided at 2000 yard intervals which deflected the CRT spot in the opposite direction to the echoes. This "A display" was universal on radars in service in all countries at this time. The antenna consisted of stacked horizontal dipoles backed by a mesh reflector, with the centre two of four stacks used for transmitting and the outer pair for receiving. The original CW set was powered by petrol engines charging 24 volt batteries, with a rotary converter to 230 volts AC. The petrol driven 230 volt alternators that followed proved unsatisfactory for continuous service and were later replaced by diesels.

The CW sets were capable of being transported by sledge dragged by a bulldozer. Accommodation for the naval crew was built close to the radars, so the total amount of construction required to set up even a simple CW station was considerable. It was carried out by the Public Works Department and there are hair-raising tales of getting machinery and equipment ashore on some of the islands or remote capes on the mainland. Subsequent fuel supplies were at times brought in by packhorse. The first CW sets had the broadside antenna mounted on the side of the radar hut, and the hut itself was rotated to scan in azimuth. Control was manual, and in a high wind the operator had to call for assistance to achieve an azimuth scan! Later sets had a separate antenna and control was electromechanical, but the antenna was fed by flexible coaxial cable, which meant there were strict limits to the range of azimuths that could be scanned. Wear and tear on the gear boxes and the operator's nerves in the frequent gales was severe and the occasional disaster occurred. The total area of a broadside antenna approached 20 m^2, and the reflector was 50 mm wire netting, so the loading in a high wind was considerable.

The radars were initially set up on site by physicists and engineers involved in the design and construction, and the Navy crew trained in operation and maintenance. The latter was helped by the fact that they had been given a special course on radar (initially by an ex-science teacher recruited by DSIR) at the Naval Radio Training School in Auckland.

With the RCA 834 transmitting tubes ranges up to 25 to 30 km on a 10,000 ton freighter were achieved. With the more powerful GEC VT90 "micropup" tubes installed from mid 1941 ranges over 40 km and sometimes approaching 50 km were obtained from the higher elevation sites. Early in 1942 a CW set was installed on Mbengga Island covering the approaches to Suva, Fiji's capital and main port. (The radar site was on the 360 m summit of the trackless jungle-covered island, and *everything* had to be hand-carried from where it was landed on the beach - quite an operation!). Overall the simple CW radar sets did great service, and the programme was fully justified by the audacious activity of German raiders around the New Zealand coast(7).

In 1943/44 these simple CW sets were phased out, and replaced by more sophisticated microwave sets (see below).

COASTAL DEFENCE (CD)

Range-finding for the guns defending the main ports of Auckland, Wellington and Lyttelton was by "depression range-finders" (effectively an optical base equivalent to the height above sea level) which were, of course, valueless in fog or darkness. The development of a radar for fire control was urgent, and started at Wellington early in 1940. The transmitter/receiver/display combination of the first set was identical to the CW, except that the time-base was displayed on a 30 cm cathode ray tube. In order to obtain good directivity the first CD set (installed at the Motutapu battery near Auckland) had separate 4-stack broadside antennas for transmitting and receiving. They were mounted on the sides of two manually rotated huts which were turned in synchronism by the operators communicating with each other by telephone! In 1941 the transmitter of this set was moved into the receiving hut and connected to a Yagi antenna, simplifying the operation enormously.

The first CD set for Wellington's Palmer Head battery was installed, without significant trials, in a tiny enclosed space at the fort, and after a few days continuous operation it overheated to the extent it became unusable! The design team had to devise better cooling, and learnt the bitter lesson of the need for robustness in military equipment, and the (not unreasonable) unforgiving attitude of military personnel to defects in equipment they are expected to use in action.

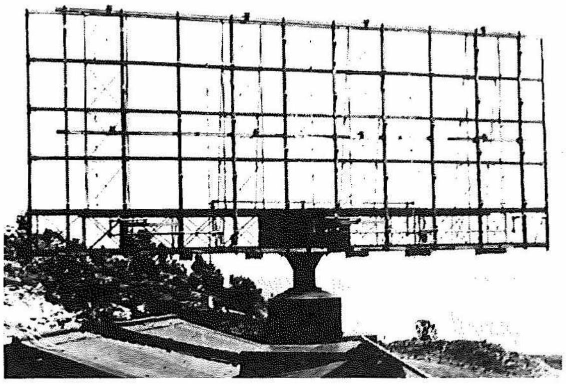
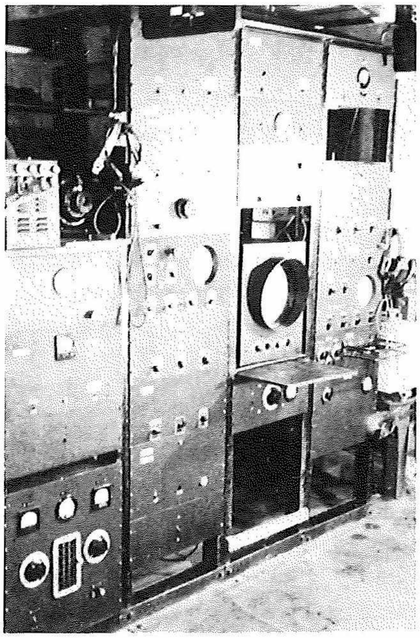


Fig. 2. 5-stack broadside array.

The closeness of the Palmer Head battery to the Post Office laboratory in Wellington allowed more thorough experimentation with antennas than had been possible at Auckland. In both places this had to be confined to daytime to allow radar operation at night, which did not help matters. The ultimate design reached by late 1940 had the three centre stacks of a five-stack broadside array for transmitting and the outer pair for receiving (Figure 2). The relative phasing of the latter was alternately switched between two different values causing the antenna beam to swing backwards and forwards in azimuth by 6 or 7 degrees. On the display the timebase was moved a small amount laterally in synchronism, so a pair of target echoes appeared side by side, and then the antenna azimuth was adjusted until they were of equal amplitude. With an effective horizontal beamwidth of 10° an operator could thus read azimuths to better than a quarter of a degree under good conditions.

During 1941 a number of improvements were made to the CD radars. The VT90 transmitter and a much improved receiver with coaxial resonator tuning on the RF and local oscillator stages became available, and two 15 cm CRTs were added to the display. One had a selectable expanded section of the timebase for accurate ranging and the other displayed the split target echo while beam switching. A much sturdier and more powerful antenna rotating system, designed by the Christchurch branch of RDL and the Public Works Department, also became available and allowed satisfactory operation even in a considerable gale.

The improved set was installed in stages at Palmer Head through the middle of 1941, while a second (originally intended for Motutapu) went to a coastal battery guarding Suva in Fiji after Japan entered the war. Further sets were made by industry (Figure 3) largely in Wellington, but not without problems as the experienced radio engineers discovered the wide differences between so many circuits in radar and those in radio communications. In all eight CD radars were supplied to the Army, the remainder of New Zealand's needs being met by the purchase from Australia of ShD



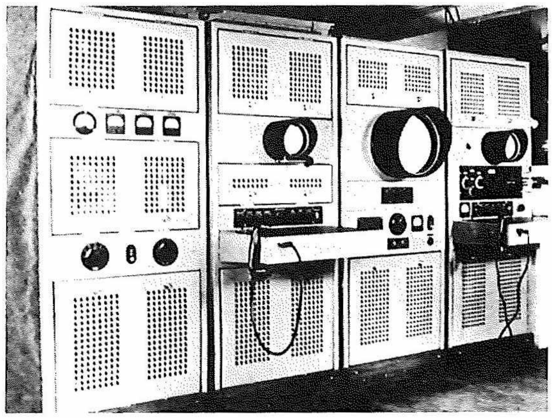


Fig. 3. CD Radar — Laboratory model (upper) and final version (lower).

(Shore Defence) gunnery control radars which also operated at about 200 MHz. Eventually these sets were replaced in 1944 and 1945 by the CD Mark 3 microwave radar manufactured in Great Britain.

Unlike the Navy, the Army initially relied on the DSIR to train personnel to operate and maintain the sets. After recruiting to cover the needs of established technical services the Army then selected those they thought might be suitable to handle what was to them a new-fangled device of uncertain capability. The author of this article had the experience of training two such far from ideal groups at Palmer Head; it was noticeable that the second was of better quality than the first as the Army got more faith in the "hurdy-gurdy"! The training problem eased substantially from the middle of 1941 when the first Service graduates who had been through the special university radio physics course appeared on the scene.

SHIP WARNING GUNNERY (SWG)

When the pocket battleship Graf Spee was scuttled in the River Plate estuary in December 1939, the aerials of the radar set designed to direct the fire of the ship's guns were plain to see(8). It turned out later that a lucky hit had disabled the radar early in the action, which had enabled the New Zealand cruiser Achilles and HMS Ajax, with no radar themselves, to manoeuvre safely hidden by smoke screens between brief appearances to fire on the battleship. A young RNVR lieutenant on Achilles, S D Harper (in peacetime a research worker at the British Post Office electronics laboratory), realized how narrow had been the cruisers' escape, and resolved that his ship would not fight the next action blind. He prevailed on the Wellington Navy Office to second him to Professor White's team in Christchurch to design and build a radar set capable of directing the fire of the ship's main armament.

As an interim measure an experimental radar was hastily assembled in Christchurch and Wellington and installed on Achilles in July 1940 while Harper started his own design. With experience in both electronics and servicing ships at sea he rejected the "rack and panel" construction used by the Post Office and adopted a filing cabinet principle with sliding drawers that pulled out on trailing leads. By putting wiring on top and valves underneath inspection and servicing could be carried out with the equipment operating. This revolutionary design was highly successful, and was adopted as standard by all wartime radars subsequently built in New Zealand. To ensure accurate ranging he used a crystal controlled oscillator at 164 kHz (providing 1000 yard range markers) and divided down to 2050 Hz to trigger the transmitter pulse and generate a timebase. The frequency was 430 MHz (wavelength 70 cm), the highest that could be practically attained with components available in New Zealand at the time, and the antennas a pair of multi-element Yagis mounted on robust shafts of galvanised water pipe. Two sets of this design were built in Christchurch and installed on the NZ cruisers Achilles and Leander in 1941 with the antennas on the fire-control tower. With a ship range of 7000 yards (against less than 5000 yards on the experimental model), range accuracy of 50 yards (500 yards) and quoted azimuth accuracy of 1°, they were a vast improvement on the experimental model(9). Both sets operated successfully until replaced by production models (see below).

In 1941 as the Japanese threat developed the British Admiralty enquired of New Zealand whether radar sets could be manufactured for the Eastern Fleet based in Singapore. Five air warning (SW) based on the CW design and five SWG based on the Harper design were promised. Later the SW order was cancelled, but the SWG order increased to 30, although only 24 were ultimately delivered, including eight to the New Zealand Navy. To attempt such production on an urgent basis required vast effort which was based at a subsidiary RDL laboratory at Auckland and local industry engaged to manufacture. Improvements included increased transmitter power using VT90 "micropup" tubes, a display with range "pips" in a "ruler-type" arrangement less prone to reading errors, and capability to show a selected portion of the timebase on an expanded scale for accurate ranging. In spite of delay in supplies, the first set was delivered in February 1942 and the remainder by the end of the year. Of those dispatched first to Singapore and later to Tricomalee in the Indian Ocean there is reason to think that one at least fell into Japanese hands, complete with its manuals; sadly there seems to be no record of any of them being installed.

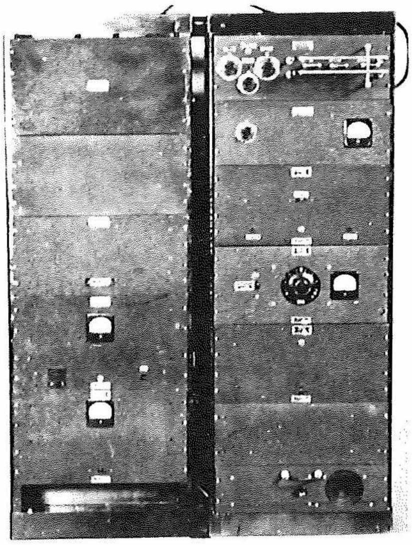
WORK FOR THE ROYAL NZ AIR FORCE

On his return from England in October 1939 Dr. Marsden had with him an incomplete ASV (Air to Surface Vessel) radar. A receiver was added by the group in Wellington and early in 1940 New Zealand's first airborne radar was flown in a Waco aircraft. It had a range of 20 km on the 5000 tonne inter-island ferry Rangatira. Subsequent development was based in Christchurch with Professor White's group and a special Air Force unit, and a set produced along the lines of the British ASV Mark I(10). This used the squegging oscillator principle for the transmitter at about 200 MHz and B-scope display. The transmitting antenna gave a fan-shaped forward-looking beam and two receiving antennas were arranged so the echoes from each would be of equal amplitude only when the target was dead ahead of the aircraft. A rotary switch connected the two antennas alternately and the echoes deflected the CRT spot to the left and right of the vertical time-base.

The transmitter and receiver of the CW and CD radars were adapted for use in aircraft, and the first set installed in an Oxford gave ranges approaching 30 km on the Rangatira. About 20 ASV sets were produced by the Post Office Workshops in Wellington and Christchurch and installed in Vincent and Oxford aircraft up to October 1941. Further development ceased when the better-performing British ASV Mark II became available from July 1941.

The wide use of the ASV Mark II in New Zealand and the Pacific necessitated the provision of ASV beacons to assist aircraft to return to their home or Allied base. These were designed by the RDL and RNZAF units in Christchurch, and transmitted a coded response via an all-round-looking antenna after triggering by an ASV signal (Figure 4). The beacons for the Pacific Islands were "tropicalized" to ensure that the electronics would stand up to the humidity and moulds that would be encountered. Their performance over average ranges of 100 miles was equal to that of the US sets bought later(11).

Whereas in Britain defence from air attack was the top priority, in New Zealand it was of less importance than coast defence until late 1941 when Japan entered the war. How-



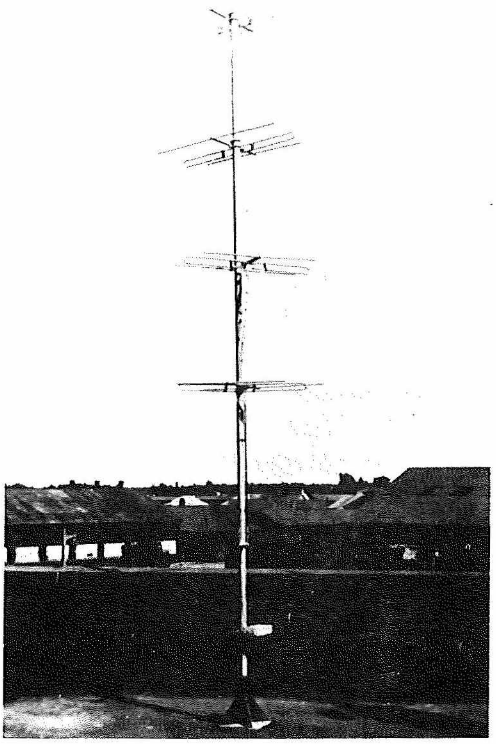
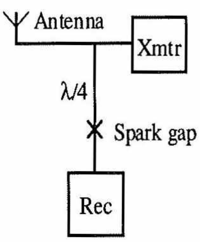


Fig. 4. ASV Beacon. Responder (upper) and antenna (lower).

ever by this time ground radar for RNZAF needs had already been ordered from Great Britain, and RDL involvement was limited to assistance in the installation where necessary, and sometimes the supply of alternatives to missing parts. An overseas version of CH (Chain Home), COL (Chain Overseas Low) and GCI (Ground Controlled Interception)[5] were involved. An old COL, previously used for training purposes by the Air Force, was installed on Malolo Island off Nandi Aerodrome in Fiji in February 1942, and several COLs by the Air Force in the Solomons in 1943.

Of particular interest was the fitting of the first successful T-R (Transmit-Receive) system in New Zealand to a CH radar on the Coromandel Peninsula. In this system a single antenna is connected to both the transmitter and receiver. A spark gap at an appropriate point across the transmission line protects the receiver when the gap fires during a transmitter pulse. The system used a locally made spark gap, and did away with the necessity of providing a receiving antenna on a separate mast.



In early 1943 as the Allied operations in the south Pacific turned more to the offensive, RDL gave further assistance in setting up a GCI radar in Guadalcanal in the Solomons. As a result of this experience it was recommended that the set would be much more useful if mobile. Following a request by Admiral Halsey, the Allied Commander in the South Pacific, two sets were each put in a 6-truck convoy by RDL. The first was set up at Munda in the Solomons by the RNZAF in September 1943, and the second on Bougainville. The pressure ventilation incorporated in the operating trucks proved to be a real boon in the tropics.

MICROWAVE RADARS

In 1939 it had been appreciated in Britain that metre wavelength radars would never be satisfactory for night fighter aircraft to engage an enemy bomber, both because of the extra drag and the lack of precision in azimuth that was achievable by practicable antennas. Research into methods of producing useful power at a wavelength of 10 cm, and of detecting such waves, was started late in 1939. By the middle of 1940 the cavity magnetron was producing powers of several kilowatts at this wavelength, and the klystron used as a local oscillator enabled their successful reception. Microwave radar was possible, and within months its enormous potential on land, sea and in the air was being realised. It is now history that the secret of microwave radar was taken to the USA in October 1940. In a far-seeing move the US authorities set up the Radiation Laboratory of the Massachusetts Institute of Technology (MIT) to develop and exploit the new technique, and at the same time to gear industry to manufacture on a large scale. Another important device that had been invented in Great Britain in May 1940 was the Plan Position Indicator (PPI) display, originally developed for the GCI radar[12] which had a "rotating coupler" in the transmission line to the antenna allowing it to rotate continuously. In the PPI display a radial time-base rotates (in synchronism with the rotation of the antenna) from the centre of a CRT and

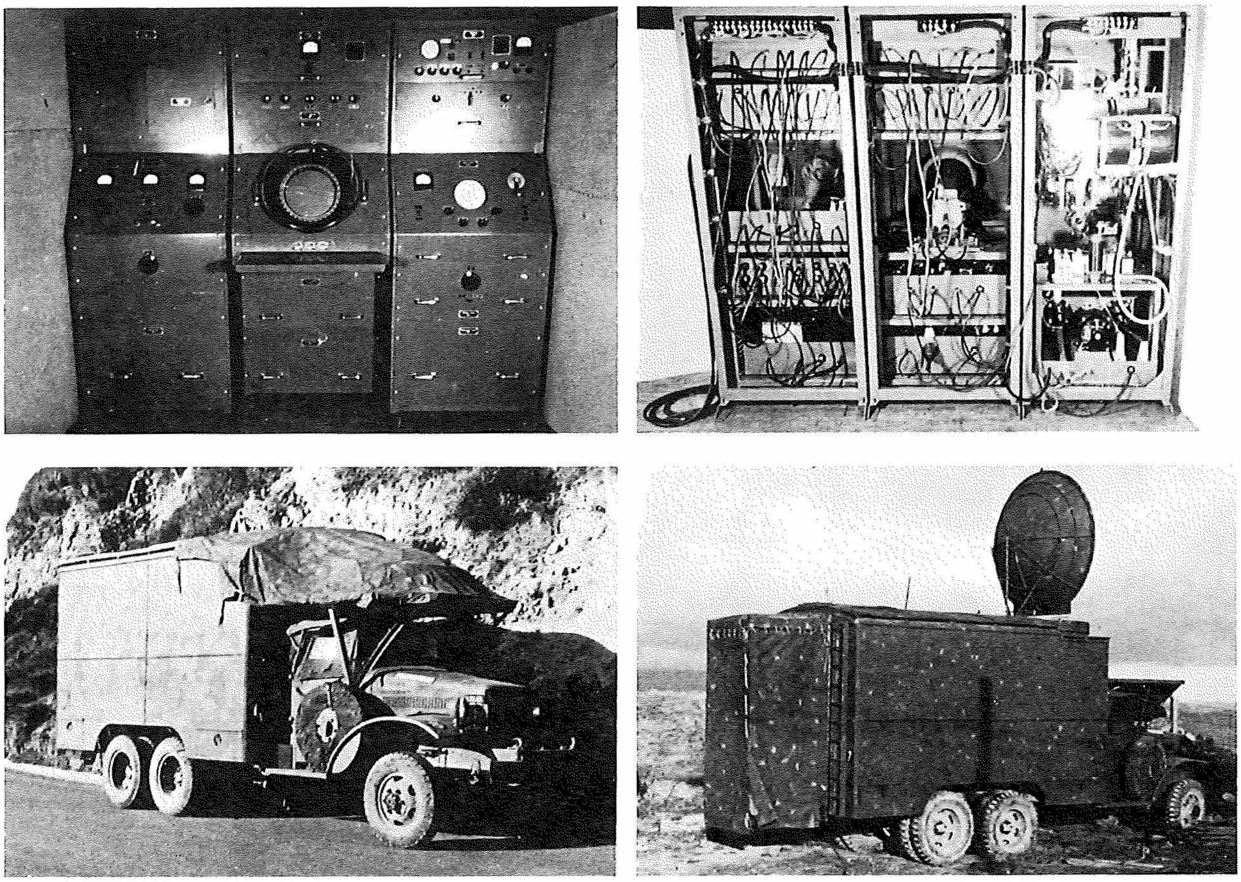


Fig. 5. Microwave Radar. Front view (top left). Rear showing trailing leads (top right). Radar truck with dish antenna stowed for transport (bottom left) and with antenna in operating position (bottom right). The interior of the truck showing this equipment appears on the cover of this issue.

is brightness modulated by the echo signal and, when required, range markers. In this way a map of the area surrounding the radar is presented, from which the azimuth and range of the desired target, appearing as a short arc, may be pinpointed. The PPI display enabled the full potentialities of microwave radar to be realised, and, with its derivatives, is at the heart of every modern radar alongside the cavity magnetron.

Late in 1941 Watson-Munro was appointed "Scientific Liaison Officer" (SLO) at the New Zealand legation in Washington DC with the prime objective of learning microwave techniques at MIT and obtaining a supply of critical components. He returned in May 1942 with magnetrons, klystrons, parabolic aerial dishes etc. supplied by the USA and Canada under "lend lease". With the subsequent permanent appointment of a Washington SLO (one also in London) the continued availability of these critical components in New Zealand was assured, and enabled a vigorous programme of development and construction of microwave radars to be maintained. Almost as important, the subsequent flow of technical literature, originating in both Great Britain, the USA and Canada, was ensured, relieving the semi-vacuum in library facilities that had existed in the early days at RDL. The magnetrons originally brought to NZ by Watson-Munro were designed to operate at 9.2 cm, a wavelength that was maintained in all microwave sets built in New Zealand in World War II. To help build up the nucleus of a team two RDL physicists spent a few months in Australia where microwave work had already begun.

In a far-seeing move it was decided very early in the microwave programme that a mobile coast-watching and surface fire control radar be designed with the thought that it could be available for service anywhere in the Pacific, and be operational within a few minutes upon a chosen site. Even with the critical components available the amount of design and development work involved for the first microwave radar was enormous – all the RF components such as coaxial transmission lines (there was no experience in waveguide theory and practice in New Zealand at the time), rotating coupler, T-R system etc., spark-gap modulator, a PPI display and so on. In the middle of 1942 the state of the war in the Pacific demanded the greatest urgency and with the recruitment of local industry in Wellington and Christchurch, and the Electrical Engineering School at the University of Can terbury, the first mobile microwave radars were in full production early in 1943 following the firing up of the first pre-production model at RDL on Christmas Day 1942. Because the radars were to operate as mobile units in the Pacific the normal standard component and chassis assembly was modified to increase robustness and resistance to vibration, and all the electronics were "tropicalized".

The radar itself was mounted in a ten-wheeler truck with the antenna dish on a rear platform initially, but in later models on the roof of the cab to allow a larger radar cabin with room

"in the first half of 1943, the mobile microwave sets produced in NZ were well ahead of contemporary efforts by the USA and Australia in the South Pacific"

for a plotting table and communications (Figure 5). A second truck contained three petrol generators (later two Lister diesels) with a workshop bench and tools. A supply of hand tools to enable first- or even second-line servicing in the field was considered essential, and, to ensure that the initial production run of 12 sets was fully supplied, late in 1942 two of the office staff of RDL visited *every* hardware shop in New Zealand and virtually exhausted their stocks of these items! Plenty of spare parts and essential electronic test gear such as oscilloscopes, standing wave detectors, test oscillators, vacuum tube voltmeters etc., designed at RDL were also sent out with each radar set.

After assembly and installation in the trucks by RDL staff the radars were fully tested in rough conditions by driving up river beds, and setting up and operating on various coastal sites. Results were highly satisfactory, well repaying the hard work that had gone into their production. After arriving at a *level* site the radar could become operational in no more than ten minutes, but up to 30 minutes if significant jacking up of the trucks to level them was required. There is no doubt that, in the first half of 1943, the mobile microwave sets produced in New Zealand were well ahead of contemporary efforts by the USA and Australia in the South Pacific. Early in 1943 the first truck-mounted microwave radar saw service in the Russell Islands in the Solomons, in the defence of a US motor torpedo boat base. An RDL scientist and a NZ Navy lieutenant were seconded to serve with the US 3rd Raider Marines, controlling the fire of a battery of 155 mm mobile guns ("Long Toms"). Further mobile microwave sets, manned by the NZ Navy, were sent to other points in the Solomons in April and June, in support of both the US and NZ forces operating in the area. Other RDL scientists visited some of these radars in operation, ensuring that lessons learned in the field and improvements and adaptations foreseen as desirable were incorporated where possible in later models.

As well as seeing service in the Pacific, the microwave radars gradually replaced a number of the 200 MHz CW sets in New Zealand from late 1943. Four sets were constructed for minesweepers operating in the Pacific Islands, their design and fitting requiring detailed planning because of space limitations. A bridge-mounted PPI display (now standard practice on virtually every radar-equipped vessel afloat) allowed the navigator to have ready access to the screen. Several of the CW microwave sets were re-modelled for detection of low-flying aircraft and truck-mounted for mobile operation by the British operating from India, but never saw service before the war's end. The last microwave radar designed at RDL was for height finding, and used for tracking radiosonde balloons by the Meteorological Service. Six of these sets were built and continued in operation until the last was replaced in the early 1960s.

LONG-RANGE AIR WARNING (LRAW)

Following the landings of US Marines in the Solomon Islands in the middle of 1942, it became apparent that there was a need for a long-range air warning set that could be quickly deployed after a landing. The transportable US air warning radar (SCR 270) took up to three days to bring into operation, whereas air warning was required virtually immediately following a landing.

In 1943 a radar operating at 100 MHz was designed, and, again with the help of industry, the Public Works Department and Canterbury University Engineering School, six were produced in a remarkably short time. As with the microwave equipment the sets were truck-mounted — the first of three trucks contained the radar equipment and a demountable moderate gain Yagi on the roof, the second contained two diesel powered generators and workshop facilities, and the third contained components for a high-gain broadside array and its mounting tower. Following coming ashore in a landing craft and being driven to the site, the radar could be brought into operation using the Yagi antenna (Figure 6) in about half an hour. It took about a

Fig. 6. LRAW radar truck with Yagis erected.

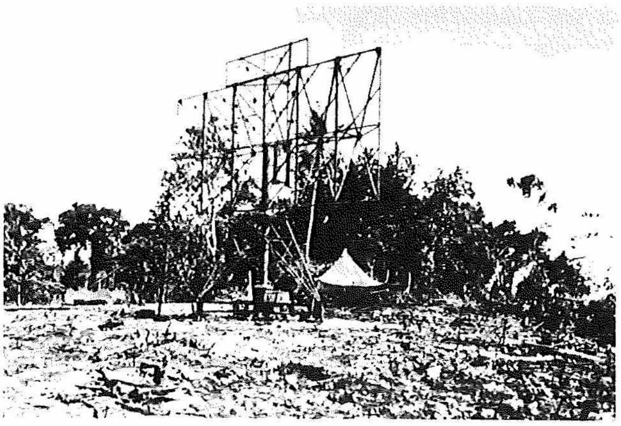


Fig. 7. Broadside array (replacing Yagi in Figure 6) in operation.

day to erect the broadside array (Figure 7). Ranges of 150 to 200 km on aircraft flying at 3000 m were normal.

The LRAW sets were assigned to US Navy "Argus" units with an RDL physicist (temporarily seconded to the NZ Army), who had been closely involved in the assembly and testing, accompanying each one to train the Argus personnel in operation and maintenance and take part in its use in military operations. The first LRAW was dispatched from New Zealand in December 1943, and took part in the landings on Nissan Island in the Solomons in February 1944. It performed extremely well and received much favourable comment from the US Command [13]. Other sets went to Emirau Island (Bismark Archipelago), Peleliu (Palau Islands) and Ulithi (Pacific Islands Trust Territories). In all cases the performance was good, allowing for deficiencies in siting in some cases, and the decision to have an RDL expert in charge, who was determined to get the best out of the set, was amply justified.

ASSISTANCE TO ALLIED OPERATIONS IN THE PACIFIC

Although not strictly within the topic of this article, the development of radar in New Zealand, another important activity of RDL scientists, in 1942 and 1943 particularly, was the fitting of US manufactured radar sets on to so-called attack transports. These sets, in ex-factory packaging, were hoisted aboard as these ships left USA shores, the intention being to fit them at the earliest opportunity, which in some cases turned out to be a short stopover in New Zealand. At this time there were very few US radar experts in the South Pacific, whereas the RDL scientists with experience of designing and building radars from first principles and installing them in ships, were ideally suited to undertake the installations. It was not unusual to be faced with a previously unseen radar set, complete with manuals, and to be asked to install it in five days while the ship was in dry dock! It was demanding and exhausting work, but of great value to the US forces. For example, all the attack transports for the landings at Tarawa in the Marshall Islands (now Kiribati) were fitted with radar in this way at the Wellington floating dock. There were installations on many other US vessels, and a T-R system was devised for the antennas of a Dutch cruiser operating with the Allied navies in the South Pacific.

Until late 1943 little was known of Japanese radar in the Pacific, but in November of that year much evidence came in that they had a variety of both land-based and seaborne equipment. An active countermeasures programme was needed, and a new headquarters unit to coordinate Allied countermeasure activities in the area was formed, which included personnel from all the Allied countries operating in the Pacific theatre of war[14]. Two RDL scientists were seconded to this group in December 1943, operating from New Caledonia and the Solomon Islands, and subsequently from New Guinea, Morotai and the Philippines. Their activities included intelligence, accompanying missions for radar search and destroy, and jamming enemy radar on raids to major targets, and continued until the war's end in August 1945.

SUMMARY

From small beginnings late in 1939 New Zealand was able to develop radar sets of increasing sophistication throughout World War II and put them in the field in New Zealand and the Pacific sometimes well before sets of similar capability could be made available from elsewhere. Because of limited facilities mass production was not attempted, but with the very full cooperation of local industry, small numbers of radars incorporating new applications were produced in a very short time between concept and placement in the field. This achievement was all the more meritorious as there was no television industry as a basis, and no one, at least at the outset, trained in any way in what was an entirely new invention. In all, 117 sets of many different types were delivered to the Armed Services, including 76 to the Navy and seven to the US Forces in the Pacific[15].

Articles, long or short, learned or off-beat (see THE BACK PAGE), News or Views, Letters or Guest Editorials are all welcome. Please submit directly to the Editor-in Chief or through one of the Editors listed on page 2. Plain text sent by email is fastest and most convenient to the Editor, but send print-out or disk (see Editorial for optimum) if you include mathematical equations. Photographs or other graphics (line drawings) are wanted for most articles at the rate of about one or two per printed page. These should be in the right size for printing without scaling.

RDL personnel in New Caledonia, January, 1944. From left: S. E. Slatter, the author, E. R. Collins, and C. N. Watson-Munro.

It should be stressed here that no equipment put into the field was complete without detailed operational and maintenance manuals. The writing and printing of these was a demanding job, and in many cases the only people who could supply the basic information were already heavily committed to furthering other urgent work. This sort of thing is only one example of the dedication of staff to the radar development programme, and their willingness to work long hours when necessary under conditions which were often far from ideal. Even so, the job had its lighter moments — examples of these could fill a book. Like the operator at Motutapu who missed reporting the liner Queen Elizabeth anchored 2000 yards from the front door – "Sorry, sir, I thought it was an island", or the pilot's comments about a radar operator whose ASV set had the left/right antennas connected right/left to the display, or the interference from a microwave transmitter under test causing an irate citizen from next door to the RDL building to complain that he was nearly blasted out of the room when he was listening to Christmas carols on the radio, on Christmas Day too! The list is endless, but unfortunately not for this article.

It would be appropriate to end this brief account of the development of radar in New Zealand with an acknowledgement to the late Sir Ernest Marsden, who launched the programme in 1939 and by his continued enthusiasm and encouragement did a great deal to ensure its success. Sir Ernest believed that "all an administrator could really do was to create the atmosphere in which research could take place, to stimulate his officers with ideas and to see that they had adequate facilities"[(16)]. He did this to great effect in the radar development programme in New Zealand. His contribution to this development, and through it to the war in the Pacific, was very great and should always be remembered.

ACKNOWLEDGEMENTS

In the preparation of this article I am indebted to a number of my former colleagues in the Radio Development Laboratory who have provided information on their personal experiences, refreshed my memory on many aspects of the programme that had escaped me after a lapse of fifty years, and provided comments and criticism on the draft manuscript. I K Walker provided an excellent report on the CW, CD and SWG programmes, while E. R. Collins covered a great deal of the earliest days in 1939 and 1940. Others who should be mentioned include, in alphabetical order, I. D. Dick, A. D. Gifkins, C. G. Liddell, Prof. A. G. McLellan, N. B. Manssen, S. E. Slatter and Dr. R. M. Williams. I would also like to thank Bruce McMillan of Eclipse Radio and Computers in Dunedin, whose recent research into the history of the World War II radars guarding that port has turned up much useful information from the wartime records of the Public Works Department and the Services, and which he has made freely available to me.

REFERENCES

1. Price, A., 1967. "Instruments of Darkness", William Kimber, London, p. 56.
2. James, R. J., 1989. *IEE Review*, October, p. 343.
3. Breit, G., and M. A. Tuve, 1926. *Phys. Rev.*, **28**, p. 554.
4. Rawlinson, J. D. S, 1985. *Proc. IEE*, **132A**, p. 441.
5. Cockroft, J. D. and others, 1985. *Proc. IEE* Special Issue on Historical Radar, **132A**, No. 6.
6. Price, A., 1984. "The History of US Electronic Warfare, Vol. 1". The Association of Old Crows, USA. This book contains useful summary accounts of the development of radar in the USA, Germany and Japan.
7. Norris , B., 1991. "Germans Laid Mines off Lyttelton in 1941", *The Press*, Christchurch, NZ, 24 August.
8. Price, A., 1967. ibid., p.17.
9. Burbidge, P. W., 1952. "New Zealand Science in World War II", Unpublished report, Auckland Public Library, ref.no. NZ/MSS/804, p. 3.27.
10. Smith, R. A., R. Hanbury-Brown, A. J. Mould, A. G. Ward and B. A. Walker, 1985. *Proc IEE*, **132A**, p. 359.
11. Burbidge, P. W., 1952. ibid, p. 3.42.
12. Rowe, A. P., 1948. "One Story of Radar", University Press, Cambridge, p. 64.
13. Burbidge, P.W., 1952. ibid, p. 3.63.
14. Price, A., 1984. ibid, pp.136-137.
15. Atkinson, J. D., 1976. "DSIR's First Fifty Years", Wright & Carman, Wellington, p. 48.
16. Taylor, N. H., 1969. In "Sir Ernest Marsden, 80th Birthday Book", A. H. and A. W. Reed, Wellington, p. 84.

NOTE BY EDITOR

The developement of defence radar in NZ before and during WW II owes much to Ernest Marsden. The following was gleaned from his "80th Birthday Book"[16] which Bob Unwin lent me.

Like NZ's greatest physicist, Lord Rutherford, he was another Ernest, though he was a Briton who spent most of his life in NZ, while Rutherford was the other way round. His work in Rutherford's Laboratory with Hans Geiger in 1909 which lead to the discovery of the atomic nucleus, was done when he was only 20. Largely as a result of this he was appointed Professor of Physics at Victoria University College, Wellington, NZ, in 1914, when he was still only 25.

He took up this position in 1915 but joined the NZ Forces, serving with the rank of Lieutenant, later Major, with the NZ Divisional Signals Co. in France. Meanwhile, his friend and collaborator, Hans Geiger, was caught up on the other side. A quirk of fate found them fighting on opposite sides of the trenches in the same sector of the front in France. There Marsden received a letter from Geiger, forwarded through Neils Bohr in Denmark, congratulating him on his appointment to the Chair in Wellington which he returned to in 1919.

ABOUT THE AUTHOR

Robert ("Bob") S. Unwin is well known to many URSI people for his pioneer work in auroral radar. After graduating from the Canterbury College of the University of New Zealand in 1940, he worked in the New Zealand Post Office and Scientific and Industrial Research Department on radar development and operations in New Zealand and the Pacific, including two years in radar and radio countermeasures in the South and South-West Pacific theatres of war. In 1946/47 he headed a joint NZ/UK investigation on meteorological effects on radio wave propagation, and continued research in this field both in New Zealand and the U.K. until the mid-fifties. From mid 1957 he headed a DSIR and university team established at Invercargill in the south of the country for studies of the aurora australis and related phenomena during the International Geophysical Year. His research interest remained in this field (particularly auroral radar) through the remainder of his career in DSIR, first at Invercargill then at the PEL Auroral Station* which he set up at Lauder in the South Island, and from 1971 as superintendent of the Geophysical Observatory in Christchurch. He was awarded a D.Sc. by the University of Canterbury in 1982, and now lives in retirement at Wanaka.

* Now the DSIR Physical Sciences Atmospheric Station.