Complemento C

CENT'ANNI DI RADAR

di Gaspare Galati

RADAR IN RETROSPECT
DI TOM IVALL

A REPORT FROM AN IEE SEMINAR HELD TO CELEBRATE 50 YEARS OF RADAR DEVELOPMENT (1985)

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FEATURES

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by Tom Ivall

Radar in retrospect

Report on IEE seminar marking fifty years of radar development

"The myth that we entered the war as the sole possessor of radar has of course long since been exploded. The Germans had been developing radar since 1934 and entered the war with the Freya early warning system on 2.5 metres, a wide deployment of Wurzburgs on 50 centimetres, a naval radar on 80 centimetres, and an airborne radar on 60 centimetres. Until our development of centimetric radars the German systems were superior to ours."

This was Sir Robert Cockburn, a former director of the Royal Aircraft Establishment, on Britain's radar in the 1939-45 world war. He was presenting a paper at the IEE's celebratory seminar on fifty years of Radio Detection and Ranging, "The history of radar development to 1945", held in London, 10-12 June.

It was not only Sir Robert's comments that made it abundantly clear, to anyone in doubt, that other countries besides the UK made important contributions to the development of radar. Papers given by American, Dutch, German, Italian, Japanese and Swiss authors, with accounts by British authors of French and Russian work, gave a pretty full picture of what was essentially an international achievement.

Paradoxically, though, a large part of this combined achievement wasn't co-operative but competitive — under the fierce stimulus of war. The UK's leading work in airborne microwave radar, for example, only became available to Germany and its allies when British aircraft were shot down and their radar sets were salvaged and studied.

The notion put about some decades ago that Britain "invented" radar would certainly not have been swallowed by anyone with even a general knowledge of radio science and engineering, let alone the radar specialists.

The basic principle — reflection of electromagnetic waves from objects — had been known to the whole scientific world for over half a century. After all, as early as 1865 Clerk Maxwell had recorded his belief that light was an electromagnetic-wave phenomenon — implying the possibility of reflection — and Hertz had rapidly shown that reflection was indeed a reality soon after he had demonstrated the existence of e-m waves in 1888.

From then on, physicists and experimenters in several countries observed the phenomenon of radio wave echos, and a few speculated on possible uses of this effect. The chronological table in this report, starting from a hundred years ago, lists some of the early discoveries, experiments and proposals that led to the development of radar as a mature technology. In general it is a story of gradual progression from metre-waves to centimetre-waves, as magnetrons became more stable and powerful, and of widening application from ground stations to ship and aircraft installations. Dates are largely drawn from the IEE's seminar but should not be taken as necessarily exhaustive, authoritative or completely representative.

The table does show, however, at least half a dozen industrialized nations contributing to radar in various ways. Mr S. Swords of Trinity College, Dublin, in an excellent survey of the beginnings of radar, listed the following nine countries as having provided significant technological effort: (in alphabetical order) America, Britain, France, Germany, Holland, Hungary, Italy, Japan and Russia.

Forgetting the crude, jingoistic propaganda of the past, there is no question, though, that Britain played a very important part in the whole story, particularly under the pressure of war. To judge from the seminar, the UK appears to have made two major contributions. One was the rapid and highly effective development, production and deployment of centimetric airborne radar, following the invention of the resonant cavity magnetron by Randall and Boot at Birmingham University in 1939. The other was the early warning chain of 19 ground metre-wave radar stations built round the coast of Britain — the so-called CH (Chain Home) stations — from Orkney to the Isle of Wight. This chain was built secretly at a cost of about £10M (now roughly equivalent to £200M), was totally integrated with the RAF's system of fighter aircraft control, and was fully operational to meet the onslaught of enemy bombers by the start of the 1939-45 war.

When the Tizard Commission went to the USA in 1940 — to exchange Britain's military tech-

Chronology of early R&D leading to radar

1885 Edison (USA) patents system for collision avoidance at sea.
1888 Hertz (Germany) observes reflection of e-m waves.
1900 Tesla (Serbia) suggests radio detection of icebergs.
1904 Hulsmeyer (Germany) patents and demonstrates spark-transmitter apparatus for detecting presence of ships — the Telemobiloscope.
1916 Marconi (Italy) and Franklin (UK) note reflection of 2-m waves from metal objects.
1921 Hull (USA) publishes description of early form of magnetron.
1922 Marconi suggests use of s.w. reflections to detect and find bearing of ships.
Taylor and Young (USA) observe 60-MHz reflections from river steamer.
1925 Appleton and Barnett (UK) discover new layer in ionosphere (F) by h.f. echo sounding.
1927 Okabe (Japan) invents split-anode Magnetron.
1928 David (France) suggests use of h.f. beam for detecting aircraft.
1930 Hyland (USA) observes 60 MHz reflections from aircraft.
Franklin (UK) proposes use of centimetre waves to obtain "wireless pictures".
1931 Butement and Pollard (UK) demonstrate reflection of pulsed 50-cm waves from objects at about 100m range, using rotating beam.
1933 Philips company (Netherlands) produces 1-GHz split-anode magnetrons.
Korovin (USSR) starts research on radio detection of aircraft.
Kuhnold (Germany) starts research on reflection technology at 2 GHz.
1934 David (France) tests 75-MHz c.w. detection of aircraft.
Kuhnold (Germany) demonstrates 630-MHz echos from a battleship.
USSR tests c.w. 64-MHz early warning radar with range of over 70 km.
Netherlands armed forces group observes reflections at 240 MHz.
1935 Tiberio (Italy) formulates theoretically the "radar equation".
Germany installs 100-MHz radar on ships.
Watson-Watt (UK) presents memorandum "Detection and location of aircraft by radio methods" to government.
Wilkins (UK) tests c.w. aircraft detection using BBC's Daventry h.f. station.
Gutton (France) installs 16-cm scanning radar on *Normandie* liner.
1936 Okabe (Japan) demonstrates c.w. Doppler radar.
Vallauri (Italy) starts research group on "radio detector telemetro".
Page (USA) produces 80-MHz pulse radar for aircraft detection.
1937 Gutton (France) develops split-anode magnetron of 10W mean power at 16cm.
1939 Randall and Boot (UK) construct resonant cavity magnetron.
1940 USA establishes civilian Radiation Laboratory to develop military microwave radar.
1943 USSR establishes permanent military Council for Radar.

nology secrets for production capacity — the US Army and Navy were so impressed by these two achievements that action followed immeditely. According to Dr E.G. Bowen, who related his part in this exchange, urgent steps were taken to put US radar systems into operational use, and orders for the manufacture of both US systems and copies of British radar systems went out to industry. "It persuaded the top [American] brass that radar was a tool of prime operational importance in modern warfare," commented Dr Bowen.

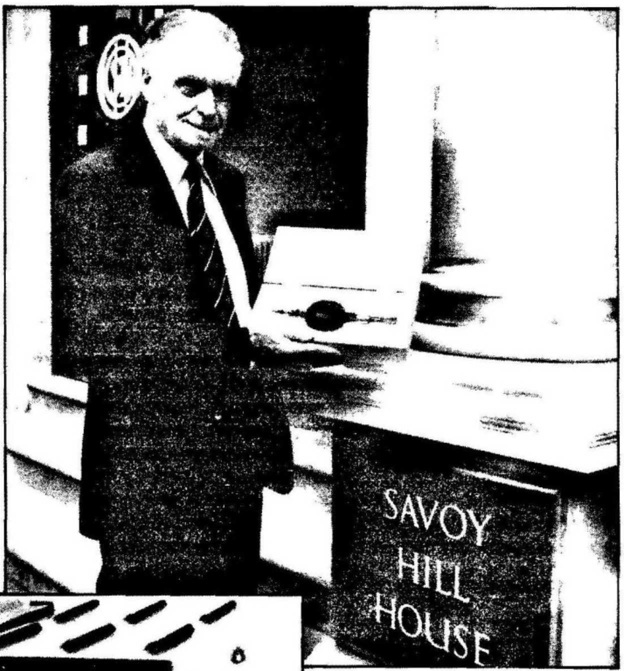
All this can be seen to have started from Watson-Watt's authoritative and now famous memorandum to the UK government in 1935, "Detection and location of aircraft by radio methods." It was certainly this document which provided the IEE with an arbitrary — though justifiable — date for celebrating fifty years of radar development in 1985. And Dr C. Susskind of the University of California, in his provocatively-titled paper "Who invented radar?", seemed to support the choice. After saying somewhat mellifluously that the development of radar followed upon "the confluence of several prerequisites brought to maturation in the 1930s" he expressed the view that Watson-Watt's memorandum stood out as the most influential of all radar publications because it was "the first to lead to the development of a system for gathering and collating radar data and acting upon them."

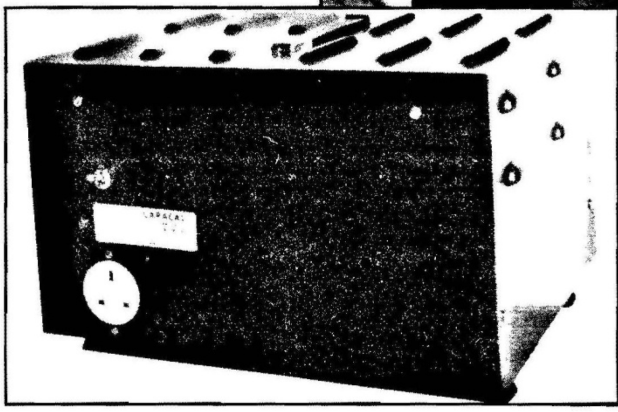
The other maritime nations that are often compared with Britain in terms of geographical area and population are Italy and Japan. As can be seen from the table, both of these countries contributed to radar development, though somewhat late in the course of events.

Italy's involvement, according to a paper by Captain R. Palandri and Professor M. Calamia, dated from 1933. In that year Guglielmo Marconi — while handing over a microwave link between Rome and Castelgandolfo — impressed the significance of radar on the Italian military authorities. (He had been, after all, a member of the Fascist party since 1923.) Then in 1935 Marconi gave demonstrations of reflection phenomena and this resulted in a report being sent to the Italian minister of defence by Professor U. Tiberio.

Soon afterwards a research group was formed at the Royal Institute for Electrotechnics and Communications. Professor Tiberio joined this group in 1936 and devised experiments to test the validity of the "radar equation" he had formulated. From 1936 to 1943 various radar systems were developed, including a frequency modulated c.w. equipment working on 200 MHz and a 70-cm pulse radar with a double horn antenna, newly developed transmitter triodes and 'acorn' receiver triodes. Manufacture of radar sets started in 1941 but met with difficulties due to the war and was finally halted when hostilities moved onto Italian territory in 1943.

Japan's contribution to radar was outlined by Dr S. Nakajima of the Japan Radio Company and by Mr Sword's survey. Dr Nakajima spoke of microwave research work by his company and the Japanese Navy's Technical Research Institute from 1932 onwards, but said nobody had practical applications in mind at that time. Research on magnetrons started in 1933, including experiments with 18 different types of anodes. Continuous power outputs of 500W were obtained from water-cooled magnetrons and wavelengths of 0.7, 2, 3, 10 and 15cm were generated.





Dr E.G. Bowen with the cavity magnetron he took to the USA as part of the Tizard Commission in 1940. The raised cylinder in the middle indicates the periphery of the resonator system; this is surrounded by circular cooling fins. On the left are the cathode and heater leads (the oxide-coated cathode being connected to one side of the heater). On the right is the output side arm.

Dr Nakajima said that in 1953 he had visited the London Science Museum and examined the Birmingham University resonant cavity magnetron on view there. He could not see any difference between it and the Japanese-developed magnetrons of the late 1930s.

In 1936 Professor Okabe, possibly influenced by Professor Yagi (of dipole fame), demonstrated detection of aircraft by a c.w. Doppler system. The following year, experiments in conjunction with the Japanese Navy achieved detection ranges of up to 5 km in Tokyo Bay. For defence of the Japanese mainland against air attack the Navy set up c.w. radar stations on ships and land operating on 1.5m, 2m and 6m. The 6m sets could detect aircraft in formation at a range of 450 km and single aircraft at 250km. Mobile ground radar for aircraft detection went into production.

Airborne radar development did not start seriously until 1942, after a captured British airborne pulse radar had been sent to Japan from Germany in 1941. But v.h.f. aircraft radar sets were produced, working on wavelengths around 2 metres. A copy of the German Wurzburg gun-laying radar was put into production in 1943 but never went into service.

In general, commented Dr Nakajima, Japan was not very prominent in radar development before 1945 because the country's research capability was in no way comparable with those of the USA and UK: for example, only A-type displays were used. He complained that he had had an R & D of 800 people working on radar and magnetrons at the time Japan entered the war, but this was cut down to a half in the ensuing years. Japanese scientists and engineers were not fully utilized in the Army and Navy Research programmes.

Most of the people attending the IEE seminar appeared to be sexa-, septua-or octo-genarians. Indeed one very lively account of radar development at the Lorenz company came from the nonagenarian Dr G. Muller — but only his recorded voice, as he had preferred to remain at home in Berlin for his 90th birthday party. Hardly anyone present seemed to be under the age of fifty.

It was a pity the young apparently showed no interest in what was undoubtedly an exciting and adventurous period of electronics history.