WHAT'S IN A NAME

PART 10

Who 'Invented' Radar?

by Greg Grant

A very good question. In fact, one you could answer – and by no means inaccurately either – by replying 'anyone and everyone'. At the beginning of this series, we saw how Appleton contributed to Continuous Wave radar and Tuve and Breit to Pulse radar. So, let's begin our inquiry by getting our definitions sorted out and then look at the people involved in developing one of the few professions whose name is an acronym.

To 'invent' something is to 'create or devise (new ideas, machines, etc.)'.* It's a 15th century word, developed from the Latin 'invenire', meaning to find, or come upon. To 'contribute', on the other hand, is to 'supply (ideas, opinions, etc.) as part of a debate or discussion.** It's a 16th century development of the Latin 'contribuere', meaning to collect.

Hardly an Invention

Frankly, a great many contributions were made to the emergence of radar, but it could hardly be described as an invention per se. It was discovered to be an inherent characteristic of electromagnetic (EM) waves, and the man who made the discovery was, perhaps, the founding father of communications engineering: Heinrich Hertz.

In the course of his groundbreaking experiments to establish the validity of James Clerk Maxwell's equations, Hertz discovered that EM waves could be reflected by both mirrors and metallic surfaces.

By 1904, the first radar patent had been granted to the Dusseldorf-born engineer, Christian Hulsmeyer. His application described a technique for, as he put it, detecting distant metallic objects by electrical waves. He tested his creation – the 'Telemobiloscope' – on the Rhine by aiming the beam at another steamer, some 550m away. The reflection from the target vessel rang a bell on the receiving equipment. Hulsmeyer, however, was ahead of his time and its technology by some 30 years or so, in fact.

Yet the idea would not go away, and some twenty years later, the great Marconi, no less, advocated a system of ship detection by radio waves, in a speech to the Institute of Radio Engineers, in New York. At the same time, A. Hoyt Taylor – whom we've already met – and Leo Gifford of the United States (US) Naval Research Laboratory at Anacostia, began experimenting with a radar operating on 5m.

With their receiver set up in a motor car and the transmitter static in the laboratory, Taylor and Clifford shortly discovered that a wide variety of metallic structures – including passing cars – made the signal strength vary enormously.

When they drove their receiver to the other bank of the Potomac River, they rediscovered what Hulsmeyer had long known. A small vessel, the 'Dorchester', wa heading down river and Taylor and Clifford noticed that 50 feet before it intersected th beam, the signal strength almost doubled. As the ship crossed the beam, the signal dropped to half its strength but, when the stern was 50 feet clear of the beam, the signal again doubled in value prior to returning to its normal level. Consequently, Taylor and Clifford suggested that this effec be used to detect enemy warships, regardless of weather conditions. The US Navy ignored the proposal.

In the following year, two engineers at Britain's Signals Experimental Establishmen at Woolwich, W. A. Butement and P. E. Pollard, built a 50m pulsed radio system for ship detection.

Aircraft Detection

There matters rested until 1930, when another Briton, W. J. Brown, writing in the Proceedings of the Institute of Radio Engineers, suggested that radio waves could be used to estimate an aircraft's height above the ground. What was surprising about this suggestion was that it hadn't been aired before. Amateur radio

* *Collins English Dictionary: 3rd edition, 1991. Page 811.*
** *As above, Page 348.*

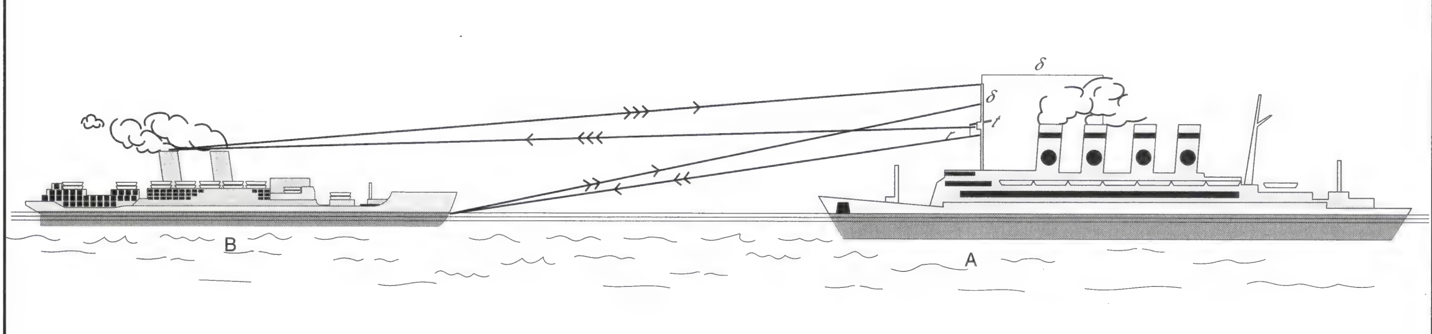

Figure 1. Hulsmeyer's 'Telemobiloscope' of 1904, from the first radar patent.

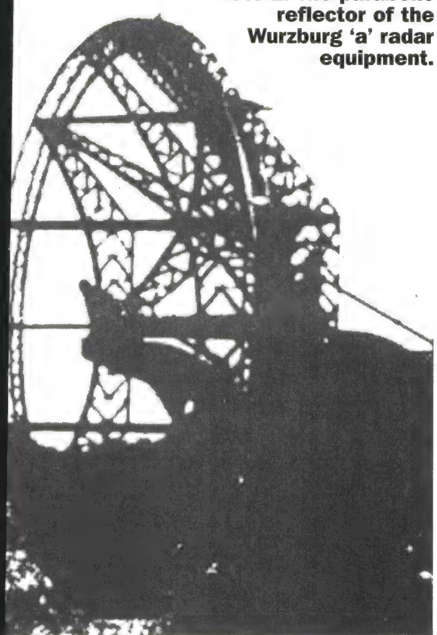

Photo 1. The parabolic reflector of the Wurzburg 'a' radar equipment.

nthusiasts, for example, had long known at aircraft passing overhead affected radio gnals and the British Post Office had also oted that aircraft regularly disturbed its ansmissions.

In 1934, the Americans revealed a 60MHz, ontinuous Wave Interference radar, whilst oth the British and Germans were becoming ore involved in radar development, but for otally different reasons.

The German Navy's Signals Research epartment was far advanced in developing nderwater detection devices using pulse echniques. In the course of this work, the epartmental head, Dr. Rudolf Kuhnold, ealised that the same techniques could also e used for surface detection.

By the late autumn of 1934, Kuhnold had hown that his transmitter, developed round a new, high-power valve from Philips f Eindhoven, could detect surface ships at even miles. More to the point, the ortuitous accident of an aircraft flying verhead in the course of the test trials, rovided another unexpected application: ir defence. Kuhnold had re-invented Hulsmeyer's 30-year old wheel!

In the following year, Kuhnold was alculating the target's distance from his ransmitter by measuring the time taken etween outgoing transmission and eceived reflection. Shortly afterwards, the German Navy had an operational radar set, vorking on 600MHz, capable of detecting other vessels at five miles and coastlines at 12 miles. By 1936, the Research Department had developed the 'Freya' radar with a range of 75 miles and the 'Seetakt' equipment, operating on 375MHz.

Two years later, the Germans revealed heir new 'Wurzburg A', an excellent Telefunken product transmitting 8kW, and using the same parabolic reflector for transmission and reception. Operating on a requency of 560MHz, it had a range of 25 miles and later developments would mprove its accuracy to within 100m and half a degree!

The Death Ray!

The British, on the other hand, had through the popular press, been seized by the idea of a 'death ray.' Today, of course, such ideas appear the epitome of absurdity, but in the mid-1930s, they were taken seriously enough for even hard-boiled realists to ask if they were feasible. One such realist was the Director of Scientific Research at the Air Ministry, Dr. H. E. Wimperis.

Along with his deputy, A. P. Rowe, Wimperis had set up a three-man scientific committee to investigate this idea and one of the individuals requested to give evidence to it was the Head of the Radio Research station at Slough, Robert Watson-Watt.

A small, opinionated Scot with granny glasses, Watson-Watt had been a physics lecturer at University College Dundee, prior to entering the civil service as a research scientist at the National Physical Laboratory. He pointed out to the committee that a 'death ray' was impossible – the power required was, quite simply, astronomical – but added that he thought radio waves could be used to detect aircraft in flight.

He firmed up his ideas in a couple of memoranda in February, 1935, and tests began almost immediately using the British Broadcasting Corporation's (BBC's) shortwave transmitter at Daventry. The target was a Heyford bomber, flying at 3·6km. Transmitter and receiver separation was 8·04km and the range achieved about 12·875km.

Wimperis's committee – the Tizard Committee, called after the scientist who chaired it – were satisfied and recommended that work should continue along the lines of Watson-Watt's memos. The little Scot, with his assistant, A. F. Wilkins and five other physicists, spent the summer of 1935 at Bawdsey Manor, on a remote part of the Suffolk coast, developing practical equipment for aircraft detection. In the course of a few months, the team had created high-power, pulsed-modulation transmitters, as well as receivers capable of handling such signals and the necessary antennas.

By September 1935, Watson-Watt's team was achieving ranges of 160km and more, as well as measuring an aircraft's height above ground through the angle of arrival of the echo. By the spring of the following year, detection ranges had increased to 145km and the Air Ministry – suitably impressed – agreed to the construction of five radar stations on the East Coast.

Chain Home Stations

By September 1938, the majority of these units – known as Chain Home stations – were up and running. One of their earliest achievements was plotting the track of Prime Minister Neville Chamberlain's aircraft as it flew to Munich for the 'peace in our time' meeting with Adolf Hitler. Shortly afterwards, the stations were put on 24-hour operation.

The Chain Home system, however, had a snag: it couldn't detect low-flying aircraft. This problem was overcome by the development of the Chain Home Low (CHL) equipment, operating at 200MHz with a range of 80km. The British didn't stop there, however. They realised that information per se is useless unless processed in a usable manner. Consequently, they developed a fighter control system where the radar images were plotted on an operations map of the radar coverage area. This gave the Senior Fighter Controller and his staff an excellent overview of the enemy build-up and hence the impending battle, enabling him to deploy his own aircraft to maximum effect.

In France too, radar was under development. As early as 1934, Societe Francaise Radioelectrique scientists began looking into metric and decimetric techniques, the object being the saving of life at sea. In the following year, what was termed an 'Obstacle Detector' was installed on the liner 'Normandie'. It was decimetric and employed pulse techniques and a second model was installed at Le Havre, to control the port's traffic.

In the US meanwhile, L. A. Hyland, a friend of Hoyt Taylor, accidentally discovered that aircraft interfered with radio signals, whilst his colleague Leo Young developed a pulse system that gave the same results.

The US Navy, however, remained considerably underwhelmed and it took the persistent pushing of the Navy Laboratory's head, Robert Page, before the Service reluctantly parted with $100,000 for further

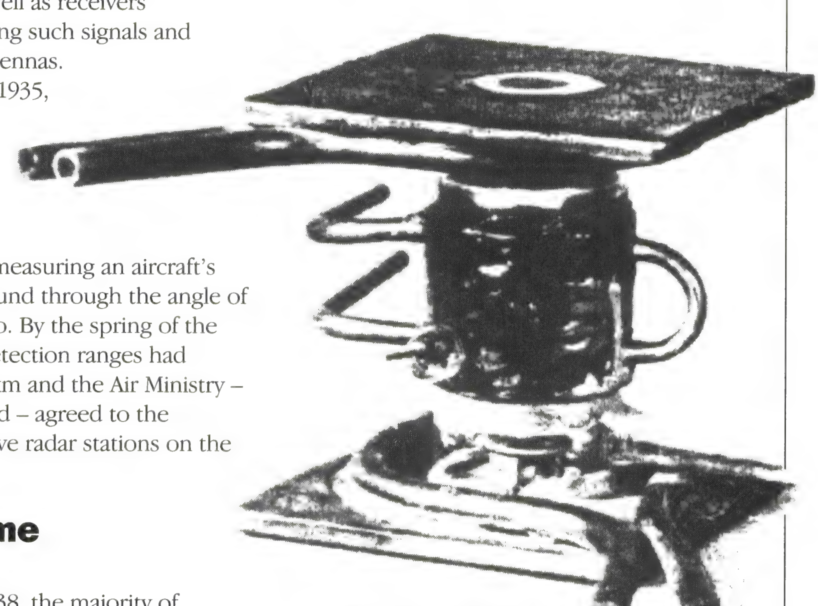

Photo 2. One of the earliest Cavity Magnetrons.

radar research. By 1938, two years after intensive laboratory work and demonstrations, the American Navy got around to fitting radar in a few of its warships.

In 1937, Birmingham University appointed a new Poynting Professor of Physics, Mark Oliphant. He was shortly joined by his first senior researcher, John Randall, who'd had considerable industrial experience in luminescence research with the General Electric Company (GEC). Also in the physics department at this time was a student called Harry Boot, working towards his BSc degree. The stage was set for the next major development in radar.

The Klystron

Oliphant was unusual in that he thought war was only a matter of a year or two away. He therefore felt that radar would have to progress beyond its present point and so, on a visit to Stanford University in America in the spring of 1939, he wasted no time in studying the newly invented Klystron.

The creation of the Varian brothers, Russell and Sigurd, the device first appeared in 1937, using an idea first put forward by a Stanford University physicist, William Hanson: the Cavity Resonator.

The Birmingham team initially thought that the klystron could, with further development, give microwave radiation at 10cm. This wavelength was important for many reasons such as, for example, far smaller antennas producing narrow beams, which wouldn't be neutralised by ground reflections. Another reason was that size was vital in an airborne context, both as regards antennas and equipment.

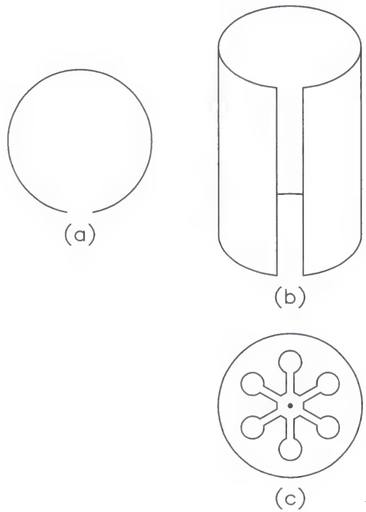

Figure 2. The cavity resonator, from (a) the Knockenkein Coil of Hertz to Randall's extension of it into a cylinder (b), to the final Cavity Magnetron (c).

The klystron rapidly proved to read better than it lived, the team deciding that it couldn't deliver a high enough power output. Then, Randall recalled that there was one other source of microwaves that might be worth looking at: the Knochenhaur Coil, used by Heinrich Hertz as a receiving antenna in his early experiments. Randall thought that you could expand the loop into a cylinder and the gap into a slot. You could then group several such slots around a centrally located cathode.

It sounded simple and, strangely enough, the first device was simple, cut from a block of copper in December, 1939. With a DC voltage applied between cathode and anode, the electron flow was in a direct path across the intervening space. When the device was placed in a magnetic field, however, the electrons followed a circular path, setting up oscillations in the slots in the copper block.

Power and Refinement

After a little more refinement, the prototype was ready for testing in February, 1940. To Randall and Boot's astonishment, the power output was some 400W! Randall's inspired back-to-the-future suggestion, indeed to the first name in communications engineering, had given radar a terrific impetus, one that continues to this day.