

MARCONI RESEARCH CENTRE

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A HISTORICAL SURVEY OF THE MARCONI RESEARCH CENTRE

by

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ABSTRACT

A short summary of the principal technical activities of the Marconi Research Laboratories from the construction of the first building on the Great Baddow site in 1938 to the formation of GEC Research Limited in 1985.

KEYWORDS

History, Marconi Research, Great Baddow Laboratories.

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## 1. INTRODUCTION

The seed from which the Marconi Research Laboratories (now the Marconi Research Centre, a unit of GEC Research Limited) were to grow came from the grounds of the Villa Griffone, near Bologna, where the young Marconi carried out his first experiments on the generation and transmission of wireless waves. Their existence had been predicted by Maxwell and demonstrated by pioneers such as Hertz, Lodge and Branly, but their potential for use first in communication and later in radio and television broadcasting was only established by many years of disciplined research by Marconi and others of his generation.

Marconi formed his company in London in 1897 with the name the Wireless Telegraph and Signal Company, changed some three years later to Marconi's Wireless Telegraph Company. For some years the research work was carried out by Marconi himself with a number of colleagues amongst whom were C.S. Franklin, Captain H.J. Round and Dr J.A. Fleming (later Sir Ambrose Fleming), who was Scientific Adviser to the Company from 1900 until his retirement in 1931. All three were prolific inventors and many patents were registered in their names. (Some appreciation of their contribution to the development of the Company in its early years may be obtained from W.J. Baker's "A History of the Marconi Company" - published by Methuen.)

In 1912 a Research Department was formally constituted under Franklin in a small building near to the Company's Hall Street works in Chelmsford, but with the outbreak of the First World War it came under the direction of the Admiralty, to whom all the Company's activities were largely devoted until 1919. In 1921 the Research Department was reconstituted, this time under the direction of Captain Round, but the decision was taken to form a separate Research Department under Franklin, perhaps an indication that great minds do not always think alike!

In 1916 Marconi had carried out some early experiments on the generation and propagation of short waves and the topic was regarded as of such importance that Franklin and his small team were asked to devote most of their attention to it. In 1919 T.L. Eckersley, who was to become one of the world's foremost experts in the theory of propagation of electromagnetic waves joined the Company and the results obtained by his researchers encouraged Marconi to believe that a worldwide communication system based on the use of short waves was practicable. Practical research work carried out by Franklin and others confirmed (and often anticipated!) the theoretical predictions. A link using a wavelength of 15 metres was established between Hendon and Birmingham in the early 1920's and in 1923 signals radiated from Poldham in Cornwall were received on Marconi's yacht Elettra in the South Atlantic, on a wavelength of 97 metres and less. That this was possible, in spite of the fact that (as we now know) the experimenters were not using the optimum frequencies to achieve minimum path attenuation, was due to the systematic research work which they had carried out on r.f. power generation and on antenna configurations. In 1924 the company received a contract from the Post Office and successfully put a worldwide system (the Empire system) into operation.

In 1930 a Television Research group was formed and in 1931 research was formally separated from development, with the appointment of H.M. Dowsett as Research Manager. Dowsett was succeeded by J.G. Robb in 1935 and the following year the decision was taken to draw together the various research teams, located in and around Chelmsford, into a single laboratory and a site

was purchased at Great Baddow, sufficiently far from possible sources of electrical interference to permit research work to be carried out on the detection and amplification of very small signals.

Building work began in 1937 and as it progressed through 1938 research staff were brought from other sites in and around Chelmsford, some into temporary huttled accommodation and others into the new building as areas were made available for occupation. (The hut occupied by Eckersley and his propagation team in 1938 is still in use by the current generation of propagation specialists in 1985!)

Completion of the buildings permitted the integration, on one site and under the direction of Robb, of a number of previously scattered units engaged on a variety of research activities. These included a telephone laboratory, primarily concerned with audio research, and led by Murphy who was later lost at sea when his ship was sunk by enemy action. Other teams were involved in propagation, low noise receivers, radio direction finding, television and specialist component studies, the latter including quartz crystal development and gas discharge devices. Most of these were of potential importance in wartime and it was not surprising therefore that very soon after the commencement of hostilities in 1939 the laboratories disappeared under camouflage netting and came again under the control of the fighting services.

## 2. THE WARTIME PERIOD (1939-45)

In April 1940 the Air Ministry took over part of the unit, including T.L. Eckersley and his team, which had been joined in the 1930's by G. Millington, also to become an internationally respected authority on electro-magnetic wave propagation. In 1941 the rest of the laboratories came under the control of the Admiralty and for the remainder of the war cooperated with the Admiralty Signals Establishment in fulfilling the urgent needs of the Services. (The Chief Scientist of ASE during this period was G.M. Wright, who had led a team working on frequency stabilisation by tuning fork and on radio facsimile transmission in the Marconi Research Department in the 1930's. He returned to the Company as Engineer in Chief in 1946.)

### 2.1 Propagation

In 1941 the Interservices Ionospheric Bureau was formed, under the auspices of the Admiralty and the RAF, to take advantage of the knowledge and expertise of the propagation team. It was reinforced by officers and other ranks from the RAF Royal Navy and US Army Signal Corps. Amongst the last were John Kojan who joined the Marconi Company's permanent staff after the war and Dana Bailey, who had come from the US Bureau of Standards and who returned there to pioneer the application of Ionospheric Scatter in the 1950's. The team devised techniques of ionospheric sounding and developed measuring equipment the results from which were used to predict the performance of h.f. radio channels. Typical of the equipment built and put into service was a pulse transmitter feeding a wide-band rhombic aerial for vertical incidence ionospheric sounding. The equipment was installed at Stock (about six miles from the laboratories) on a site with the inappropriate name of Smallgains Lane! It was controlled by telephone line from the laboratories and the delayed echoes received from the ionosphere were monitored round the clock by the RAF operators. Data assembled from measurement of this sort was circulated to all three services to guide system operators in selection of optimum frequencies for h.f. communication. (Similar information is still compiled by the Propagation Group in the Marconi Research Centre and circulated to a wide range of h.f. users via H.M. Stationery Office Publications.)

While the measurement and prediction of h.f. radio performance was the predominant activity of the propagation team in the war years, attention was also devoted to tropospheric influences on direction finding and radar systems and to many other topics referred to the specialists by service users. Dr R.V. Jones in his book 'Most Secret War' describes how his attention was drawn to a report by Eckersley which showed that it was possible for German bombers flying over the UK to receive guidance signals from a transmitter on a sufficiently high site in Germany. It appears that Eckersley changed his mind at a conference at the Air Ministry but his report was nevertheless the spur which led Jones to initiate the measurements which demonstrated that the bombers were indeed being directed by a beam system originating in Germany and resulted in the introduction of effective countermeasures. Jones described Eckersley as "The country's leading expert in radio propagation" and it is apparent from references in the book that his work and that of his team at Baddow were vital to the war effort.

## 2.2 Direction Finding

Another activity of considerable wartime interest and well established in the laboratories from their inception was radio direction finding, work on which was being prosecuted in several different groups. At the outset considerable assistance in the design of the receivers used in d.f. was given by Dr E.E. Zepler who had been head of receiver development in Telefunken, Berlin and with his colleague Dr Bohm, Head of Research, had been obliged to leave Germany in the mid-1930's. However Zepler as a German subject, was interned in 1940 and after gaining his freedom about a year later became a lecturer at Cambridge and subsequently the first Professor of Electronics at Southampton. Other engineers continued the work on direction finding notably in teams led by S.B. Smith and by R.J. Kemp, whose activities had been switched from television in the interest of the war effort. Work on receivers was led by R.B. Armstrong, whose team included Dr G.L. Grisdale and Mervyn Morgan both of whom were to reach very senior posts in the Marconi Company after the war. Apart from its use in propagation research direction finding was used in aircraft, ships and land-mobile equipment, in the monitoring of transmissions from the enemy and even in spy-catching. At one stage about 100 members of the Womens Royal Naval Service were using DF Sites for monitoring enemy transmissions and RAF personnel, led by D. Gill (who in post war years became manager of the Marconi Specialised Components Division), were building DF equipment for use in that service.

## 2.3 Radar

The Company had not been closely involved with the development of radar prior to the war although Marconi in a speech to the American Institute of Engineers in 1922 commented that he had observed reflections of electromagnetic waves by metallic objects miles away and suggested that this might be used for detection and determination of bearing of ships. When, following the work of Watson-Watt and others, the decision was taken in 1935 to install CH radar stations around the UK the responsibility for supply and installation of the transmitter 'curtain' arrays was given to the Company, and this work continued well into the war years. By 1942 parts for use in a naval centimetric radar were being shipped out of the Chelmsford factory. A radar calibration (EP7) designed by Norman Lea, whose team had developed considerable expertise in frequency control and timing techniques, was also used by the Navy and in 1943 a contract was awarded to the Company for development of the 960, a naval radar operating at a frequency of about 90 MHz. The transmitter was developed by the Transmitter Development Group in the main factory and the aerial, receiver and display units in the Research Laboratories. C.D. Colchester was principally responsible for the aerial and C.S. Cockerell (later Sir Christopher Cockerell, inventor of the hovercraft) for the display. First trials of the equipment were made in October 1944 and the first operational set was installed in HMS King George V in August 1945. Notwithstanding the relatively early date of design and the short development cycle the equipment embodied both sophisticated anti-jamming techniques and a built-in noise jammer.

## 2.4 Spark Therapy

One activity carried out in the laboratories during wartime was in a very different field from that normally associated with Marconi. The

Company had, during the period of depression in the early 1930's, begun to look for new outlets and had undertaken studies on the use of electro-magnetic energy in medical diagnostics and therapy. Under the leadership of A.W. Lay a small team had developed a spark generator operating at about 1 MHz for electro surgery and diathermy. Work continued during the war and equipment was supplied to the Army for surgical use in the field. The instrument known as the Marconi Ekco Therator was used both for cutting tissue, by applying intense but controlled current in the appropriate area, and for control of blood flow, by applying local heat to a blood vessel and thereby encouraging coagulation. Since operations were virtually bloodless and instantly cauterized the instrument was popular with army surgeons and the commander of the New Zealand forces wrote to Lay to tell him that his machines had saved the lives of over 1,000 New Zealand troops.

The machine, as a spark generator, inevitably radiated energy over a wide part of the e.m. spectrum and was used in one variant as a jammer against the German beam system referred to previously.

## 2.5 Components

During the war period much research was devoted to components partly because many devices were special to the equipment and partly because new component developments offered the prospect of equipment superiority relative to that of the enemy. In the second category the most important example was almost certainly the emergence of the cavity magnetron from the work of Randall and Boot at Birmingham University in 1939. The Marconi Company had in 1919 pooled its resources with those of GEC to form the Marconi-Osram Valve Company (still part of the GEC Company as M-O Valve Company) but maintained a small vacuum physics research team in the Baddow Laboratories, led by Dr Brett. At the outset of the war this was making small quantities of the Stabilovolt, a gas discharge voltage stabiliser with taps at 70 volt intervals up to 280 volts, based on a German design. The requirement for stabilised power supplies in most military equipment led to a vastly increased load, compounded by an involvement in magnetron development, on the Baddow team. Brett, who had been seconded temporarily to the Admiralty for similar work with Dr Sutton, returned to Baddow and was joined by A.J. Young, who had worked with Aisenstein in running valve manufacturing facilities for the Marconi Company in Russia and Poland. Young led the work on magnetrons, which closely paralleled that at GEC's Hirst Research Centre and the M-O Valve factory, and produced devices for centimetric transmitters being delivered to the Admiralty from the Chelmsford factory. By May 1942 demand had grown to a level well beyond the resources of the laboratories and a production unit was set up at Waterhouse Lane, Chelmsford (at peak production in 1945 nearly 2,500 magnetrons per month were leaving the factory). When the Cable and Wireless UK facilities were nationalised in 1946 and transferred to the Post Office, the Marconi Company (as the manufacturing organisation) was sold to the English Electric Company, and the valve unit became the English Electric Valve Company. In 1985 it still includes magnetrons amongst its major products.

Amongst the passive components used during the war and subsequently was the quartz crystal on which most communication and navigation systems depended. A team led by Norman Lea was carrying out research on methods of frequency stabilisation, including methods of reducing the effects of long term drift in crystals which was a troublesome problem in equipments of that generation. In parallel



T.D. Parkin and colleagues were engaged in the growth of crystal quartz and the cutting of crystals for use in the stable sources. The majority of the sources were embodied in equipment being manufactured in the Chelmsford factory and the demand grew to such an extent that production units specific to the purpose had to be set up. Over 9000 were made in 1943 with half of the Baddow Site, as well as a Chelmsford unit, being devoted to the activity. The Baddow manufacturing unit was led by D. Fairweather who in the post war years became manager of a crystal manufacturing unit at Hackbridge.

Publication of many of the activities carried out during the war years has never been made because of their relevance to national security but they can best be summarised as a sequence of reactions to national needs as they were foreseen at the time and as they developed as the war proceeded.

## 2.5 The Engineer as Wartime Citizen

This policy was not confined to the technical work. The Laboratories had its own Home Guard platoon, led by the unit's cashier, Norman Knight, and fire brigade led by R.F. O'Neill, a senior engineer involved in aerial design. In addition to their technical activities, engineers did night duties on the site as fire watchers, first aiders and telephone switchboard operators. During the day some acted as spotters of enemy aircraft and sounded Klaxons to give warning to their colleagues still at work. All were ready to respond to physical challenge as they did to technical problems when the occasion demanded it.

Research had to be devoted to short-term aims and the results embodied in practical equipment in the shortest possible time. Longer term projects such as television had to be put on one side and individuals had to adapt themselves to new roles and new challenges. However, many of the techniques and devices which emerged from the wartime work were to find application in peacetime roles later and those members of the research teams who had not moved permanently into development, manufacturing or commercial activities had developed the expertise and motivation to take on the new tasks which the end of hostilities presented to them.

### 3. THE RETURN TO PEACE

After the war ended the Service Units withdrew from the site, staff who had been seconded to work elsewhere e.g. at the Admiralty Signals Establishment or at TRE Malvern returned, and the Laboratories turned their attention to peacetime needs. The nature of the research did not however undergo a fundamental change.

#### 3.1 Frequency Control

For example there was still a need for precise control of frequency of communication channels and work to overcome the long term drift of quartz crystals was continued. The problem was eventually overcome by packing the crystals in glass sealed units (a procedure which had begun in wartime) and later in T05 cases, similar to those used for transistors. The frequency range over which crystals could be supplied was also extended from 1 kHz to 100 MHz, using flexural modes at the lower end and overtones at the upper, and frequency stability was improved by enclosing the crystals in ovens at precisely controlled temperatures. In Lea's frequency control team these developments were incorporated into frequency standards with drifts as low as a few parts in  $10^{10}$  per month which could not be surpassed until the arrival of atomic standards. An example of an equipment resulting from this work was the TME2 Frequency Measuring Equipment (a successor to the wartime TME 1) used by the BBC at its Tatsfield monitoring station and by broadcasting administrations throughout the world.

In addition to the work on oscillators of the highest stability, demanding multiple ovens with temperature control of the crystal to a few millidegrees, research into temperature control of a lower order was aimed at the achievement of frequency stability of about 1 part in a million for communication requirements. In an oven designed by D.J. Fewings, working in a team controlled by Dr. G.L. Grisdale, he used the expansion of naphthalene at its melting temperature to activate a control switch to the heater.

Many thousands of these ovens were sold by the Specialised Components Division to customers, the majority of whom were outside the Marconi group. Another successful series of crystal oscillators used transistors as rapid-heating elements, and crystals in transistor cases, with the whole assembly being contained in an evacuated miniature valve envelope to provide mass-free thermal insulation.

#### 3.2 Television Resumed

The initiative on television research and development had been lost to the United States during the war years but work was restarted in 1946 in a team strengthened by the recruitment as Chief Television Engineer of L.H. Bedford, who had been one of the leaders in radar development at Cossor's. An agreement with RCA enabled the team to obtain up to date information from which to advance their own work and by 1949 Bedford was able to demonstrate, to an audience at the Royal Society of Arts, pictures from an image orthicon camera which lost very little in either contrast or definition when the source of illumination was changed from a spotlight to a single candle. In the same year the Varsity Boat Race was for the first time televised from start to finish using a similar camera and the research team was able to turn its

thoughts to the problems involved in system improvements including the introduction of colour to the pictures.

The Marconi Company had not been involved in the manufacture of domestic radio receivers since 1929 when it sold its Marconiphone Company and the use of the copyright signature "G. Marconi" to RCA in an agreement which precluded its trading in domestic receivers for a period of 20 years. However in the late 1940's the Baddow Laboratories were given the task of designing a television receiver. This went into production at an English Electric factory at Liverpool and was marketed as the Model 1550. Some members of the team involved in its development were then transferred to radar display work and others to the problems of stable channelised aircraft transmitters and receivers.

In the meantime the studio research team was studying the problems involved in introducing higher resolution black and white systems (625 lines instead of 405) and colour. Under the direction of L.C. Jesty they made an experimental 2-tube colour camera which was used for demonstration purposes well before the decision was taken to standardise on the PAL system in the U.K., and assembled the necessary background technology to enable a development activity to be launched immediately the decision on the preferred system was known. In 1956 it was decided that system principles were sufficiently well established for the television activity to move out of the research domain and the team transferred to development activities at Chelmsford, dividing their interests between two divisions - Broadcasting and Closed Circuit Television.

### 3.3 Microwaves and Millimetric Waves

When the Laboratories were first formed a small team led by N.M. Rust was given the specific responsibility for exploring new ideas which could be used as the basis of patents, the Marconi Company from its inception having had a strong tradition for initiation and exploitation of patents. This team like others was engaged on activities specific to the war effort but as it ended began to study again how some of the ideas formulated could be used in peacetime. In the period 1946-47 J.F. Ramsay published in the Marconi Review a series of articles on Fourier Transforms in Aerial Theory which was widely used by antenna engineers throughout the world for many years, until the advent of digital computers made it possible to improve on the analytical design techniques which he employed.

Within Rust's team work also began on the possible uses of the upper end of the microwave frequency spectrum, one of the participants being P.S. Brandon - a future Chief of Research for the Marconi Company and later Professor of Electrical Engineering at Cambridge University. A magnetron to operate at about 40 GHz had been designed in the Services Electronics Research Laboratory at Baldock and was being further developed at Elliott Bros Ltd Borehamwood. Other components were designed at Baddow and used as a basis for system experiments. Very few of the components for the frequency band were readily available at this time and the Laboratories had to design and manufacture their own. In doing so they developed a number of relatively new techniques such as electroforming, and precision casting and machining and although the 40 GHz work was temporarily suspended in



the early 1950's these were applied successfully in other frequency bands and were resuscitated in the 1960's when work began on low loss waveguide transmission for potential use in trunk communications. At 40 GHz many of the techniques were quasi-optical and amongst the antenna components studied were lenses in an "egg-box" construction i.e. a 3-dimensional array of rectangular waveguides bonded together and dimensioned so that the phase change of an electro-magnetic wave passing through the structure varied over the cross-section in a way precisely analogous to that in a dielectric lens.

#### 3.4 CW Radar

Brandon and others were at this time carrying out research on FM radar and designed an S-Band system which was used to carry out experiments on a site at Benacre, near to Lowestoft. This excited interest from the Admiralty (for submarine Schnorkel detection) the army (for sentry use) and some non-military users, including the Marconi International Marine Company but did not develop into a practical system, primarily because the technology was too far ahead of the market need.

#### 4. THE ERIC EASTWOOD PERIOD

Other work such as that on direction finding, precise frequency control and measurement, and electromagnetic wave propagation continued throughout the 1940's but the Marconi Company, which had been owned by Cable and Wireless (Holdings) since 1929, became part of the English Electric Company in 1946 and this was to introduce a new personality of considerable influence, Dr. Eric Eastwood, and a new area of activity to the Research Laboratories. (F.N. Sutherland an English Electric engineer of considerable experience had become General Manager of Marconi at the beginning of 1948 and at about the same time R.J. Kemp succeeded Robb as Chief of Research.)

##### 4.1 Type 11 - The Introduction to 600 MHz Radar

It was decided to transfer the task of up-dating a little-used wartime radar the Type 11, operating in the 600 MHz frequency band, from the Nelson Research Laboratories at Stafford to Great Baddow. (The up-dating involved conversion of the relatively crude coho-stalo system of moving target indication to a fully coherent system). Although the two events were not directly connected Dr. Eastwood, who had worked on radar in No 60 Group, RAF throughout the war, for much of it with the rank of Squadron Leader, also transferred from Stafford to Baddow at about the same time in order to take up an appointment as Deputy Chief of Research. Thereafter, Kemp tended to concentrate on the longer established activities of the Laboratories and Eastwood on the development of new ones, with a particular emphasis on peacetime applications of radar.

##### 4.2 Marine Radar

Work had already begun by 1946 on the development of marine radar for use by merchant shipping. The prototype of an X-Band radar, given the name Radiolocator I, was built in the Research Laboratories by a team which included R.P. Shipway, recently returned from wartime service at TRE, and B.J. Witt. It was installed on the Duke of Lancaster, operating between Heysham and Belfast. A second prototype, Radiolocator II, followed (one model only was built) and with its successor, Radiolocator III, further development and manufacture passed to the main factory in Chelmsford. Radiolocator III was marketed in quantity by the Marconi International Marine Company.

##### 4.3 UK Air Defence

Eastwood's first major task, in which he was assisted by C.D. Colchester and Shipway amongst others, was a major study of the UK ground radar defence system carried out on behalf of the RAF and culminating in a set of recommendations for up-dating (known as Project Rotor). Subsequently this was extended to cover mobile radars also (Project VAST). The Air Ministry accepted most of the recommendations in the report in 1949 and much of the redesign and manufacturing was entrusted to a newly formed Division of Marconi's (then called Services Equipment Division and later Radar Division).

#### 4.4 Fixed Coil Display

The ROTOR plan was concerned with the re-establishment of three radar systems, CHEL (Chain Home Extra Low), CEW (Centimetric Early Warning) and GCI (Ground Controlled Interception). In wartime all had used plan position displays with moving coil deflection systems, i.e. coils rotating round the neck of the cathode ray tube in order to produce a rotating time base synchronised with the rotation of the radar antenna. In the new plan for CHEL and CEW for ROTOR and in all the VAST vehicles this technique was again employed but Eastwood advanced a convincing argument, based on a forecast requirement for data handling in radar displays, that the large GCI stations should be equipped with fixed coil displays. Deflection to the time base in the required direction was achieved by applying suitably phased voltage waveforms to two orthogonal pairs of coils. Thus it was possible to insert extra information, such as alpha-numeric data on target height, at any required position in the interval between successive time bases.

More importantly, it allowed data relevant to the position of targets to be extracted (by overlaying markers) for processing or display elsewhere. Eastwood set up a team under the direction of R.P. Shipway to examine the possibilities on specially developed equipment.

The Royal Radar Establishment of Malvern had already made preliminary studies of fixed coil displays and in work sponsored by them the Baddow team undertook a project to develop a system for use on operational RAF sites. In order to ensure the linearity and directional accuracy of the time bases the currents in the deflection coils had to be controlled very precisely and much original thought went into the analogue display circuitry. Shipway also adopted the concept of "fully toleranced circuit design" whereby from the outset of the design process, manufacturing tolerances of circuit components were taken into account, thereby minimising the problems likely to be encountered in manufacture and test, and contributing greatly to reliability of the equipment in service. Full manufacturing drawings were produced and over 1000 display units subsequently made in Marconi and Plessey Company factories.

By the end of 1953 the first displays, with the associated radar office equipment, were in operation at RAF Bawdsey.

#### 4.5 Radar Research in L. Band

Another activity begun in 1950 in association with RRE was a practical study of a frequency band which had not previously been used for ground radar in the UK. The early CH radars had operated in the h.f. band. (about 25 MHz) and the later generation, following the development of the cavity magnetron, in the centimetric bands (about 3 GHz). An intermediate band, around 200 MHz had been used for GCI (Ground Controlled Interception). The new work was centred on 1.3 GHz and it was hoped to get some of the advantages of all the other three, e.g. relative freedom from the dense clutter experienced on centimetric radars when operating in rain, considerably better detection of low flying targets than was achievable in the HF band and height finding with a single radar antenna, as in the GCI's but without the necessity