

The 1940 common aerial for 1.5 metre Australian radars..

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Introduction.

By an extensive process of experimentation in early 1940 the CSIR Radiophysics Laboratory (RPL) devised a very effective Receive-Transmit (RT) switch to allow aerial duplexing of 1.5 metre radars. This small glass glow discharge tube was mounted in a quarter wave transformer which could operate at a pulse repetition frequency (PRF) of 50 pps used in LW/AW sets with a pulse width of 10 microseconds. The glow discharge had a life of thousands of hours & was far better than anything available from England at this time.

It would appear that work in America on duplexing started in 1936 at the Naval Research Laboratories (NRL) where R M Page produced an electron switch which could protect the receiver by a momentary short circuit of a radar set (XAF/CXAM) to be mounted on large ships for air warning. This switch was subsequently changed to an ions device but the whole exercise, Page explained, produced a working result in 10 weeks based on pure faith and intuition & it was not until later that he understood the principles & processes involved.

Work in America by the Signal Corps in developing the SCR 270 air warning radar was able to be duplexed in October 1938 by a vacuum tube switch (in 1940 GA-4) invented by H A Zahl. The first Signal Corps radar was the SCR 268 gun laying set which had separate transmit & receive antenna. It was not until after the Tizard Mission in August 1940 that the exchange of technical military details from America became available to Australia.

The first radar developed for the British Army, the Gl-Mk1, was a mobile anti-aircraft fire control radar first tested in October 1937 after a year of development at the Bawdsey Research Station. It had separate transmitter & receive antenna using a wavelength of 6 metres. It was first deployed in late 1939, including with the BEF (British Expeditionary Force) to France & captured by the Germans. In operation it was not an effective unit. (In the January 1940 memorandum prepared by Watson-Watt & Madsen on shared research, no specific mention is made as to research on duplexing. A Gl-Mk1 was to be supplied to Australia in March 1940).

The British Chain Home Low (CHL) radar was introduced in July 1939 at 1.5 metres & used separate transmit (at ground level) & receive (at the top of a 185 foot tower) antenna. The CHL set was designed to detect aircraft below 1500 feet not covered by the main Chain Home tower network of transmitter & separate receive antennas.(see Postscript). By April 1941 CHL had been upgraded to duplex operation, as was used at Milne Bay by RAAF station, RS 37 very effectively.

The first Royal Navy (Signal School Portsmouth) radar in August 1938 for aircraft early warning was the 79Y on 7 metres, using separate aerials for transmit & receive, however it was the success of the Telecommunication Research Establishment (TRE) with original work on spark gap discharge tubes that pointed the way for the RPL work..

It is acknowledged by J L Pawsey & H C Minnett in documenting this early work that M I G Illiffe & H R Oliphant invented the glow discharge tube & that A L Reimann produced a diode as a possible alternative. D F Martyn & other staff of RPL made valuable suggestions.

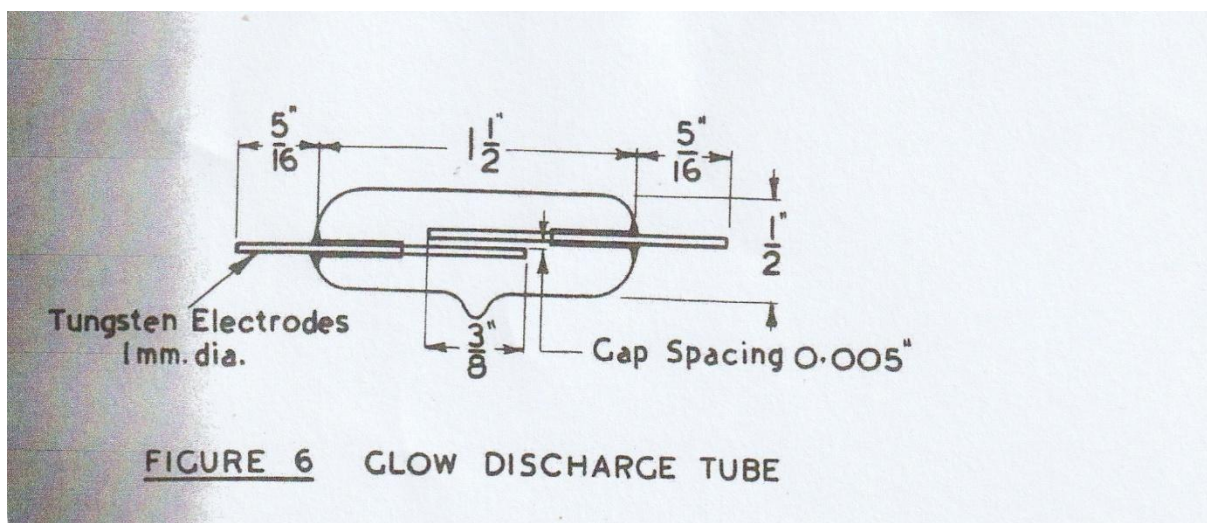
In 1907 J P V Madsen as a DSc thesis experiment measured the time it took for ions to recombine in gases after removal of the alpha particle ionising agent calculated at $1/20^{\text{th}}$ of a second which was far slower than the ionisation and recombination due to a high energy Radio Frequency (RF) pulse in gas measured in microseconds. (The ionising process of an alpha particle travelling in a short straight line is quite different to ionisation due to an RF energy pulse in gas).

The investigation of oscillations in ionised gases appears to have begun in 1929 by Tonks & Langmuir published in the Physical Review while working for General Electric.

The merits of a single aerial operation are evident such that a single aerial utilising the whole area will have twice the power gain of separate aerials each of half the area, so that an increase in the overall power gain of the aerial system of four times is thus theoretically possible.

It is noted that in both the cases of Madsen's 1907 work & the RPL work on duplexing in 1940 that extensive preliminary experiments were first carried out before reaching a conclusion'

The Glow Discharge Tube.



The tube consists of two tungsten rods sealed into a glass envelope containing argon & hydrogen at pressures of 15 and 0.5 centimetres respectively, the ends overlapping to form a narrow discharge gap. A small amount of powdered glass contaminated by radioactive material (radium) is contained in the envelope to provide a continuous supply of ions in the gap region. This was found necessary to ensure instantaneous striking of the gap when the radar equipment is switched on. The speed with which the tube becomes non-conducting at the end of the transmitted pulse depends on the rate of reduction of ionisation density between the electrodes. Inert gases have an inherently long deionisation time and recovery of the glow tube is therefore assisted by means of an electrostatic field. This is supplied to the gap from a 60 volt DC source with series resistance to limit the discharge current during transmission. Owing to the simple structure of the glass tube, the losses are very small and the tube has a high figure of merit. It was found that the life of the tube was of the order of thousands of hours provided the circuit was designed to limit the peak current to 5 amperes.

The performance of this switch with a transmitter power of 80kw (an A79 naval air warning set for the RAN) was as follows:

Nominal receiver suppression ratio. (40 decibels.) Nominal leakage power to receiver (8 watts.) Peak dissipation in glow gap (800 watts.) Peak current through gap (<5 amperes) Overall loss (1-2 decibels.)

In 1940 the first Australian operational radar at 1.5 metres using the duplex aerial was the Shore Defence (Sh.D) ship detection & ranging at 20-30 miles, operating at 10 Kw with a transmit pulse of 1.5 microseconds. The Air Warning (AW) radar built in December 1941 was a 10 Kw set based on the Sh.D electronics but with a transmit pulse of 20 microseconds to have a greater range on smaller targets. The LW/AW was the upgraded version of this set which first saw operations in late 1942.

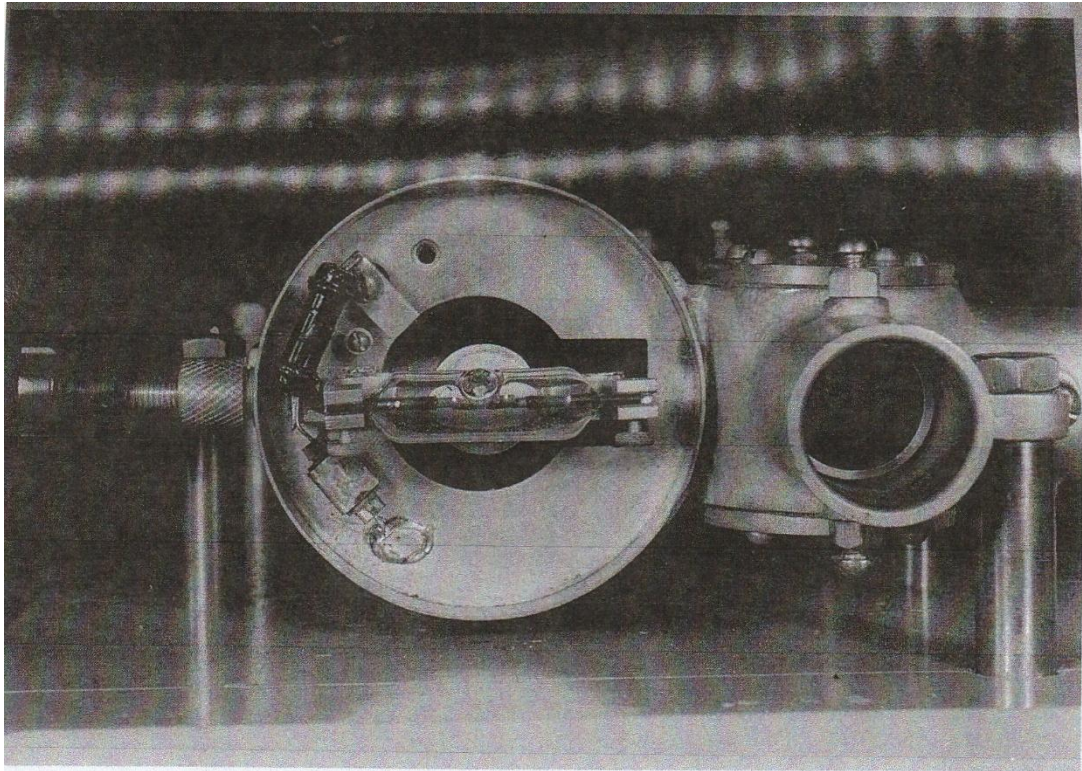
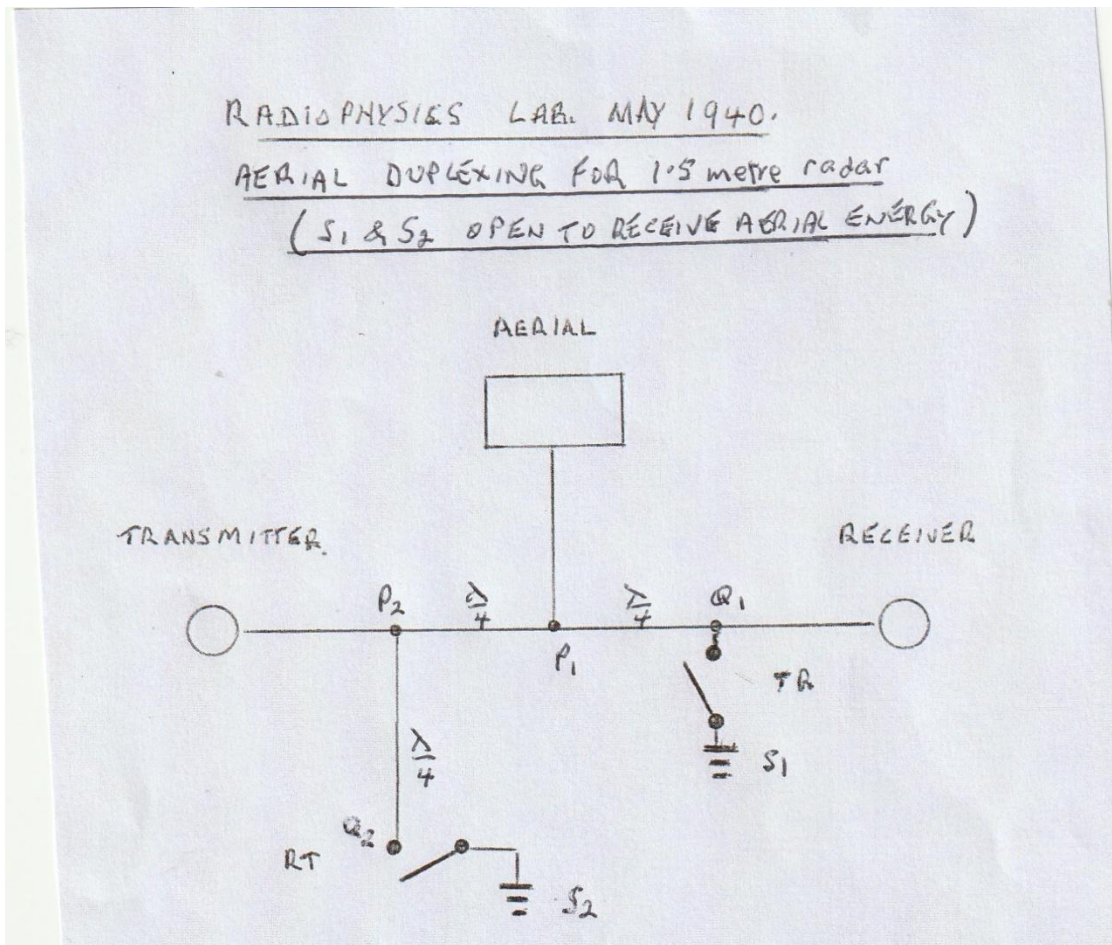


Fig. 8 Glow discharge tube mounted in one of the quarter-wave transformers of Fig. 7 - cover removed.

The Circuit Diagram for Aerial Duplexing.

The TR & RT units are represented by single throw switches S1 & S2. During the transmitted pulse both switches are closed so that points Q1 & Q2 are short circuited. These short circuits reflect as open circuits across the shunt junctions P1 & P2 owing to the impedance inverting property of a quarter wavelength transmission line. Hence the transmitted power flows to the aerial without reflection at P2 & P1 & there is no leakage past Q1 to the receiver. The transmission line section P1Q1 & P2Q2 are resonant but absorb no power as the line has been assumed loss free. All the generator power thus reaches the aerial.

At the end of the transmitted pulse both switches are opened and remain open until the beginning of the next pulse. The open circuit at Q2 transforms to a short circuit across P2 and an open circuit across P1. The echo energy received by the aerial flows to the receiver without reflection by the infinite impedance shunted across P2 & Q1. Also none of the energy reaches the quiescent transmitter.



J P V Madsen (1907) The recombination of ions after removing the ionising agent.

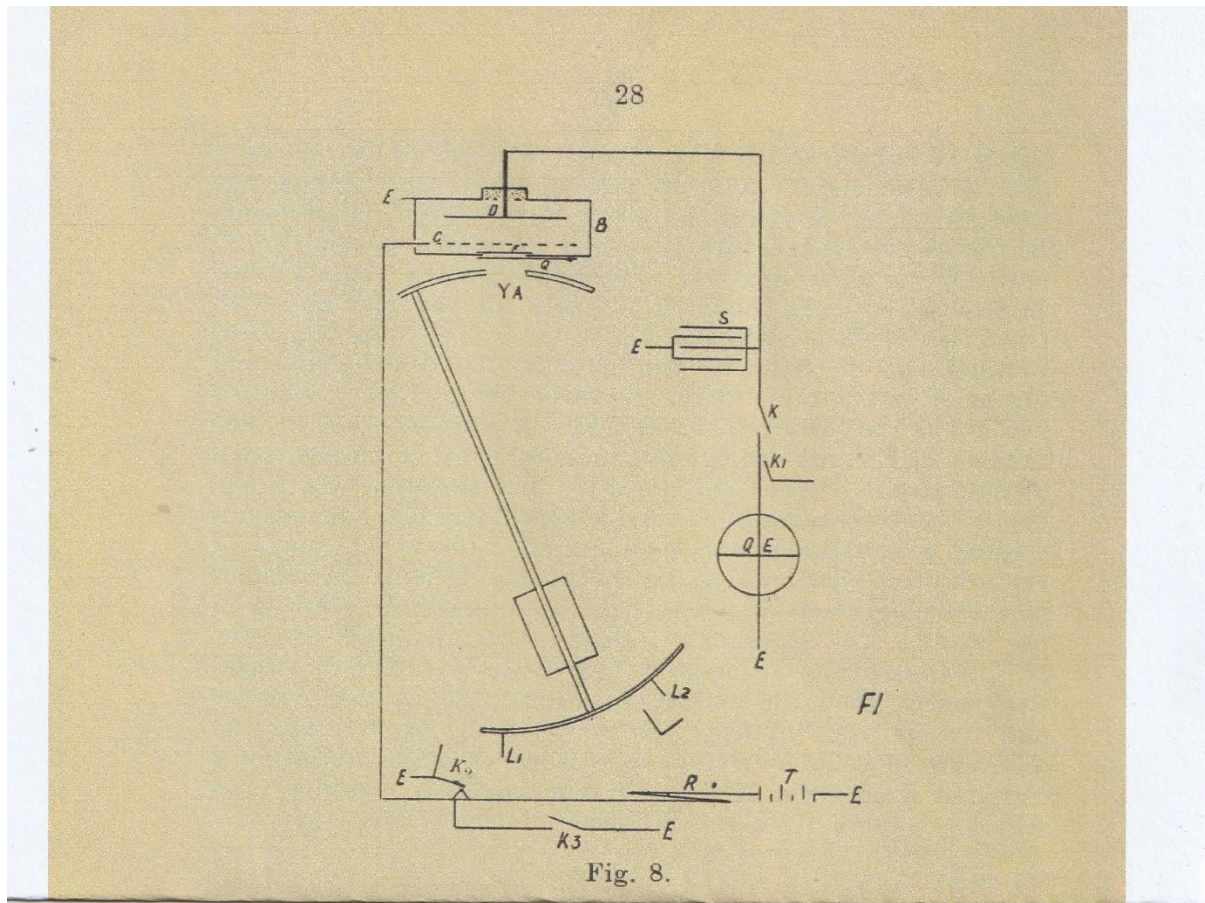
An interesting analogy exists between the cycle process of a gas discharge tube and Madsen's pendulum experiment to determine the speed at which ions in gas recombine after a "pulse" of alpha radiation is allowed to pass into gas in an ionisation chamber. The time involved is the equivalent of the RT tube recovery time.

The general arrangement was to allow alpha radiation from radium to act on gas in the ionisation chamber. A lead screen was quickly interposed between the radium & the chamber & then shortly the charge on the electrode was measured by a quadrant electrometer.

A lead plate about 2 mm thick with a 1.5 cm square was attached to the pendulum and the amplitude of the swing was such that alpha rays could pass into the chamber only for a short period during the motion of the pendulum. By an ingenious arrangement of switches it was possible to measure the time for the ions to recombine. Madsen found that the ionisation due to the path of the alpha particles had recombined within a period of 1/20th of a second after the act of ionisation.

In 1939 the Swiss American L B Loeb wrote a 10 year summary book on the "Fundamental processes of electrical discharge in gases" (Wiley NY, Chapman & Hall

London) which appears in the Fisher Library catalogue at Sydney University & may have been available to RPL in 1940.



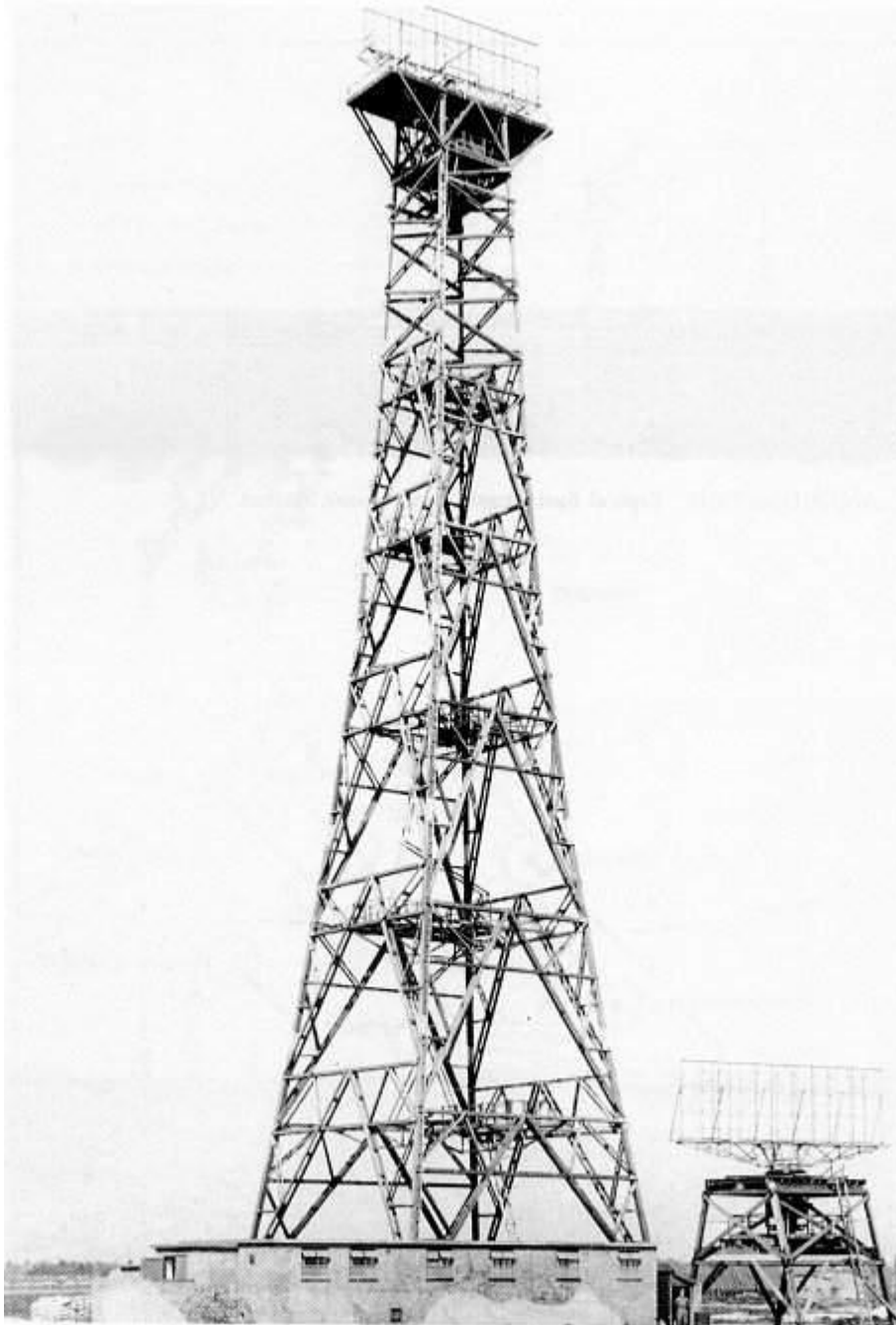
References:

CSIR RPR51 " Early Australian Developments in the use of a single aerial for transmission & reception " J L Pawsey & H C Minnett 11 September 1946.

"Text book of Radar" RPL 1954 2nd edition, Cambridge University Press. (2015)

"The Origin of Radar" Robert M Page, Doubleday 1962.

Postscript: The British 1.5 metre CHL radar July 1939.



3 AMES Type 2 CHL Chain Home Low Station (185ft Tower)

The first encounter by the British with German radar was with the Graf Spee in the South Atlantic in late December 1939. The antenna of the Seetakt ranging radar was examined by Bainbridge-Bell on the scuttled ship in Montevideo while posing as a scrap metal merchant and was found to be duplexed. It appears the Germans were using a gas discharge tube or “nullode”.