Journal of Astronomical History and Heritage, 19, 185–194 (2016).

THE EARLY HISTORY OF LOW FREQUENCY RADIO ASTRONOMY IN AUSTRALIA. 6: MICHAEL BESSELL AND THE UNIVERSITY OF TASMANIA'S RICHMOND FIELD STATION NEAR HOBART

Martin George, Wayne Orchiston
National Astronomical Research Institute of Thailand, 191 Huay Kaew Road, Suthep District, Muang, Chiang Mai 50200, Thailand, and University of Southern Queensland, Toowoomba, Queensland, Australia.
Emails: martingeorge3@hotmail.com; wayne.orchiston@narit.or.th

Bruce Slee
CSIRO Astronomy and Space Sciences, Sydney, Australia.
Email: Bruce.Slee@csiro.au

and

Richard Wielebinski
Max-Planck-Institut für Radioastronomie, Bonn, Germany, and University of Southern Queensland, Toowoomba, Queensland, Australia.
Email: rwielebinski@mpifr-bonn.mpg.de

Abstract: Following some initial research in Tasmania between 1955 and 1957, notably by Graeme Ellis and Grote Reber, low frequency radio astronomy became a significant activity of the University of Tasmania from the early 1960s, with the main aims being to study the radio Milky Way and Jupiter's decametric emissions. Although locations very close to Hobart Airport were to see the majority of this work, in the early to mid-1960s low frequency antenna arrays were set up and used by the University at nearby Penna and Richmond. This paper describes the erection and use of the Richmond arrays, which in 1962–1963 operated at a site 1 km north of the town of Richmond, and at frequencies of 2.35, 1.55 and 1.03 MHz.

Keywords: Radio astronomy, Tasmania, Richmond, Michael Bessell, Graeme Ellis

1 INTRODUCTION

Initial research in low frequency (<30 MHz for the purpose of this series of papers) radio astronomy in Tasmania in the mid-1950s generated considerable interest in this field, largely buoyed by the successful observations made by Grote Reber (1911–2002) and Graeme Reade Anthony (Bill) Ellis (1921–2011) at Cambridge in 1955 (see Reber and Ellis 1956), and subsequent observations, such as those by Ellis and Gordon Newstead (1917–1987) that were also conducted near Hobart (Ellis and Newstead, 1957).

The 1955 research had come about largely as a result of Reber's decision to concentrate on low frequency observations, although in Australia work at relatively low frequencies had begun some years earlier at Hornsby Valley, near Sydney, under the auspices of the CSIRO's Division of Radiophysics (see Orchiston et al. 2015b).

Ellis was absent from Tasmania from late 1957 until October 1960 (Elizabeth Ellis, pers. comm., 2008) during which time he took posts in Queensland and New South Wales. He then returned to Hobart in order to accept the Chair of Physics at the University of Tasmania, and his interest in low frequency radio astronomy quickly led to a blossoming of activity in this field of research.

Ellis was instrumental in selecting sites for the various arrays, and locations to the east and north-east of Hobart became the centres for the construction of several of them. The area near Hobart Airport (Llanherne) contained large expanses of suitable flat land, and this location will be discussed in a future paper in this series. Meanwhile, other sites were identified that were suitable for array construction.[1] One of these was 1 km north of the historic town of Richmond (see Figure 1), where Michael Bessel carried out research for his B.Sc. Honours degree in Physics. This paper discusses Bessell's work at the University of Tasmania's short-lived Richmond field station.[2]

2 A BIOGRAPHICAL NOTE

Michael S. Bessell (Figure 2; b. 1942) entered the University of Tasmania in 1959 with an interest in science, particularly physics, and teaching, for which he had received a teacher studentship. He graduated with a major in Physics in 1961, and with Graeme Ellis as supervisor undertook his Honours degree studies in 1962, preferring radio astronomy rather than theoretical research. Bessell's Honours thesis details his use of three low frequency radio astronomy arrays that were erected at Richmond (Bessell, 1963).

After completing this radio astronomy project, Bessell never returned to radio astronomy, concentrating instead on optical astronomy. He satisfied the requirement to begin a teaching career in 1963, but was awarded a scholarship to undertake a Ph.D. in astronomy, which he commenced in 1964 at the Australian National University in Canberra, studying variable stars under Professor Bart Bok (1906–1983).

Bessell's career in astronomy then saw him involved in many pursuits, including significant advances in photoelectric photometry, a topic in which he became a world authority (e.g. see Bessell, 2005).

Mike Bessell was appointed to a professorship at the Australian National University in 1988.

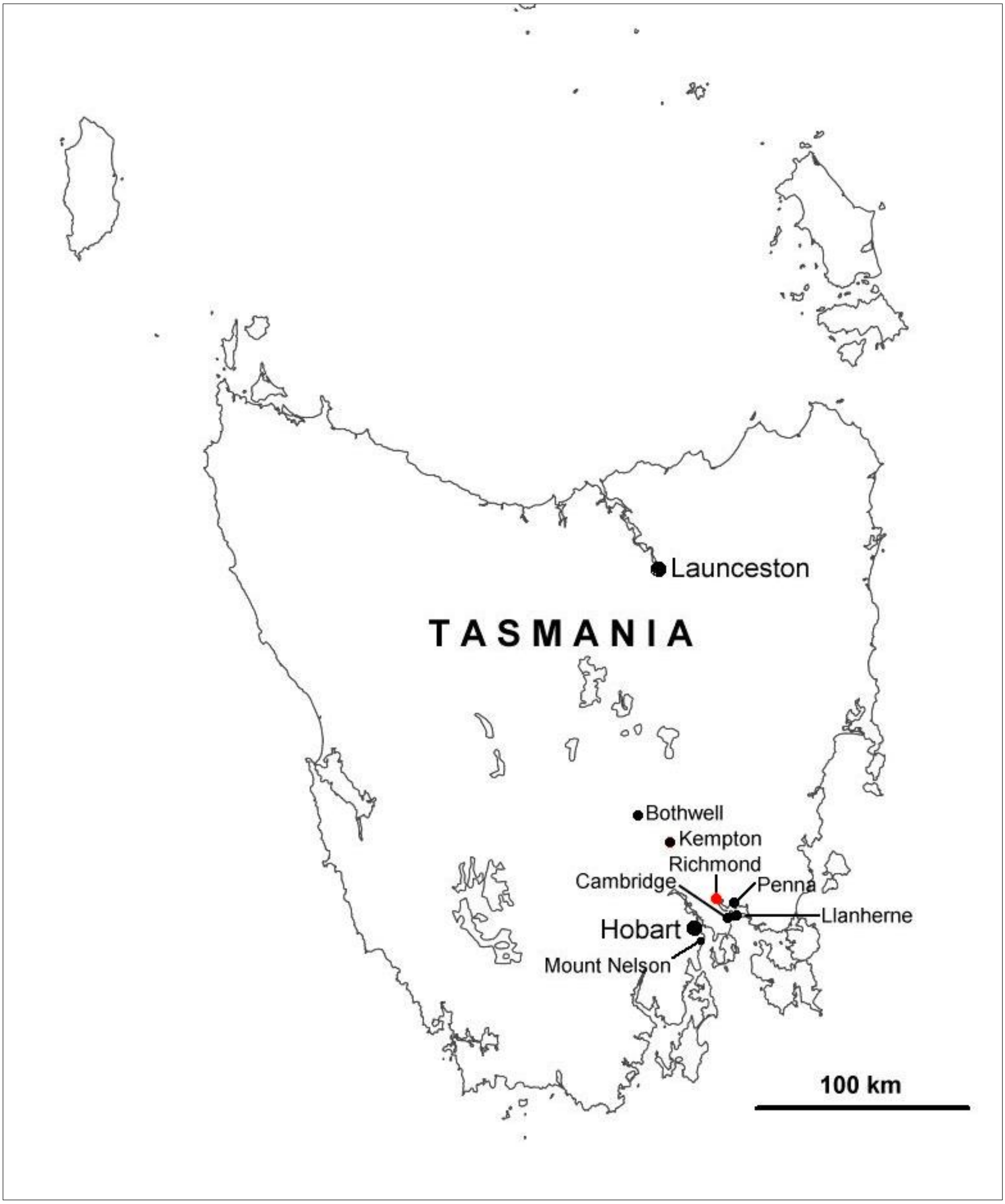


Figure 1: Key radio astronomy sites in Tasmania. This paper discusses the University of Tasmania arrays at Richmond, to the north-east of Hobart.

3 INSTRUMENTATION

The setup at Richmond was erected, beginning in early 1962, on a plot of land within a property known as 'Daisy Bank' (Figure 3), after permission was given by the owner, John Jones, who was a family friend of Bill Ellis and his wife Helen. Using an aerial photograph of the site taken in 1965 (Figure 4) which, when enlarged, shows the shadows of some poles that were then still standing (Figure 5), we have identified the centre of this plot as being at longitude 147° 25′ 48″, latitude –42° 43′ 26″ (WGS84). For decades this piece of land has been known colloquially as the 'pole paddock' (Ben Jones, pers. comm., 2016).[3]

The section of the property that was used was approximately rectangular, with dimensions of about 900 m × 280 m, and with its long axis oriented towards azimuths 280° and 100°.

The arrays were erected parallel to the long axis of this rectangular area, and therefore were not oriented exactly east-west.

Bessell (1963) describes the layout of the arrays:

> Each array consisted of three centre fed full wave dipoles supported about 23 ft above the ground. The dipoles were separated by about half a wavelength and fed in phase so as to give vertical reception. The 4.8 Mc/s dipoles were aligned in an E-W direction at Llanherne (long 147.2° E, lat 42.9° S) and the 2.35, 1.5 and 1 Mc/s arrays were in a S.E. - S.W. direction at Richmond about 5 miles away.

Figure 2: Michael Bessell in the early 1960s (courtesy M. Bessell).

Clearly, Bessell had intended to write "S.E. - NW. direction", but even this is not strictly correct, because the arrays were almost certainly oriented toward azimuths of 280° and 100°, as mentioned above.

With all three arrays, lattice networks were used to transform the impedance of the antennas so that they matched the 70 Ω coaxial transmission cables. (ibid.)

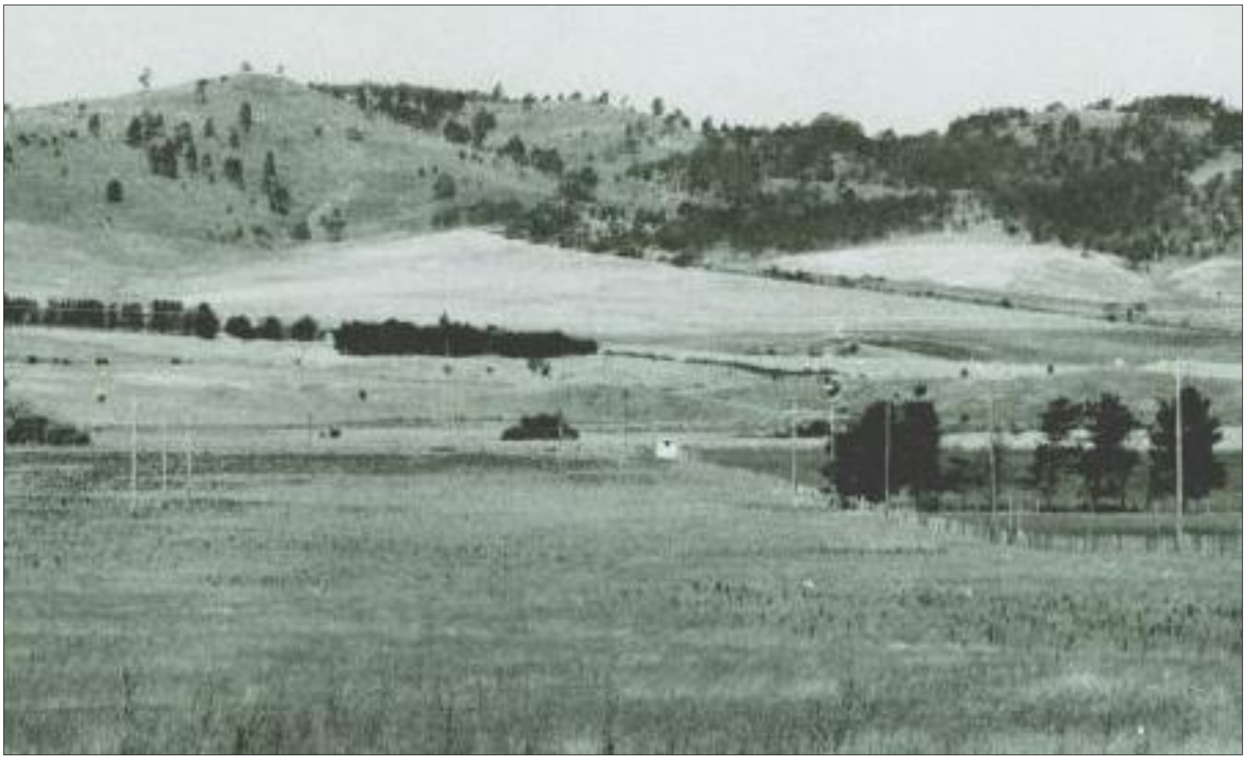


Figure 3: A panoramic view looking east south east showing parts of the Richmond arrays (the three poles on the left and the five poles along the fence-line on the right), and the hut (just right of centre) containing the receiving equipment (after Bessell, 1963).

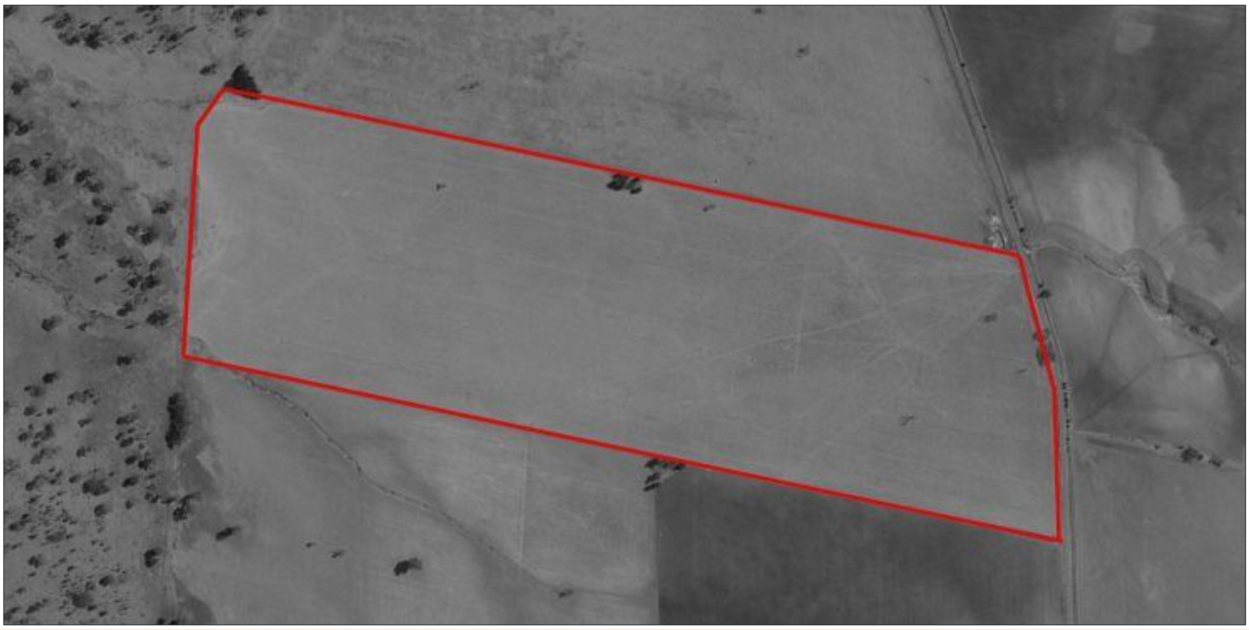


Figure 4: A 1965 aerial view of the site of the arrays at Richmond, delineated in red. North is uppermost. (Adapted from an image provided by TASMAP (www.tasmap.tas.gov.au), © State of Tasmania).

The 4.8 Mc/s dipoles to which Bessell refers were located adjacent to Hobart Airport, but were included as a mention in his Honours thesis because the results at the lower frequencies at Richmond were to be compared with the somewhat higher frequency results from Llanherne.

The poles that were used at Richmond were telegraph poles.[4] Bessell (pers. comm., 2011) recalls that as part of his work toward his Honours degree, he was required to visit the Hydro-Electric Commission at Glenorchy,[5] or the Postmaster General's Department, to purchase the cross sections for the tops of the poles.

Bessell (pers. comm., 2011) remembers:

> We made the antennas out of aluminium clothesline. We had a plastic extruder so we put plastic chips in and they got heated up and you put different moulds on them and could make whatever kind of shape needed ... [The aluminium] was in long rolls. It was essentially aluminium, multitwisted. It looks like steel, but it's just the stuff that goes on aluminium clothes-lines. It's quite strong. It's easy to bend but you can't bend it more than once. If you have to bend it again, it breaks. They worked out a way that you could easily attach it so it wouldn't come unstuck. It all went together rather easily.

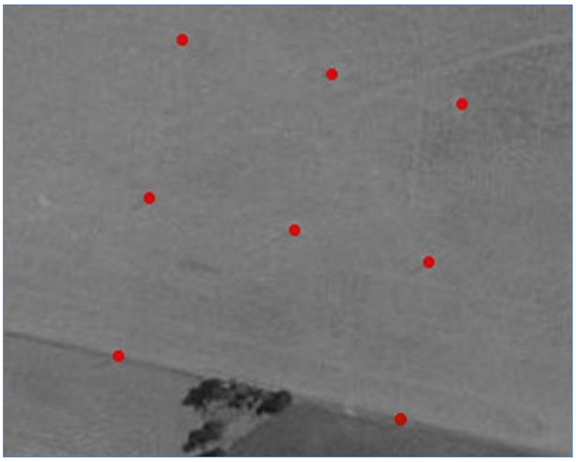


Figure 5: A close up of part of the aerial view in Figure 4, showing the bases of some poles (red dots) that were still standing in 1965, as indicated by their shadows (adapted from an image provided by TASMAP (www.tasmap.tas.gov.au), © State of Tasmania).

The arrays at Richmond originally were designed for use at 2.4, 1.6 and 0.9 MHz (Bessell, 1963). This corresponds to wavelengths of 125, 188 and 333 metres, respectively. Clearly, the losses through insufficient antenna height were considerable and we shall return to this point in the Section 5, below.

Bessell (1963) does not comment on the resolution of the arrays. Although a different resolution for each would be expected, Ellis and Hamilton (1964) state that the resolution was 32° × 40° at both 2.35 MHz and 1.66 MHz. (See Section 5 for comments on evidence that 1.66 MHz observations were carried out in 1963.)

A small timber shed (see Figure 3) was erected to house the receiving equipment. While Mike Bessel (pers. comm., 2011) recalls that it was purchased rather than built by the Physics Department, Kevin Parker (pers. comm., 2009) remembers it being constructed in the Carpenters' Shop at the University. Evidently the shed had been removed by the time the 1965 aerial photograph was taken, but it appears in two of Bessell's images. Curiously, the photographs show that it appears to have been placed near the south-eastern corner of the plot of land. This may have been to allow road access, or possibly because its position related to one or more of the arrays. Whether it was moved at any stage is not recorded.

Bessell (pers. comm., 2011) describes the contents of the shed (cf. Figures 6 and 7):

> [There were] a couple of benches. This was all done by Gordon [Gowland] and Kevin [Parker].[6] There was RAAF [Royal Australian Air Force] surplus equipment which they had large numbers of. They put these mechanical sweeps on, which gave us better data in order to get rid of these spikes.

The use of 'mechanical sweeps', to which Bessell refers, was a way of countering a major problem faced in low frequency radio astronomy: interference from local, national and international AM radio stations. The method was to sweep through a range of frequencies to find one at which the interference was minimised. As Bessell recalls (ibid.),

> When there weren't Chinese broadcasts coming in, we could pick up the Galaxy going through.

The sweeps were effected by slowly driving the rotor of a variable capacitor (Figure 7), resulting in slight changes in the resonant frequency of the receiver.[7]

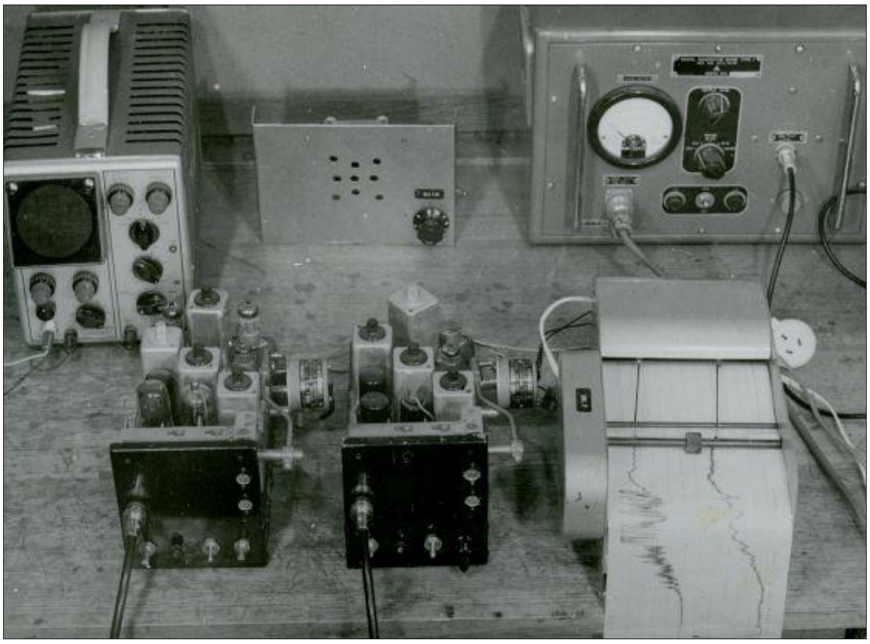


Figure 6: Equipment used in the shed at Richmond. The chart recorder can be seen at right (after Bessell, 1963).

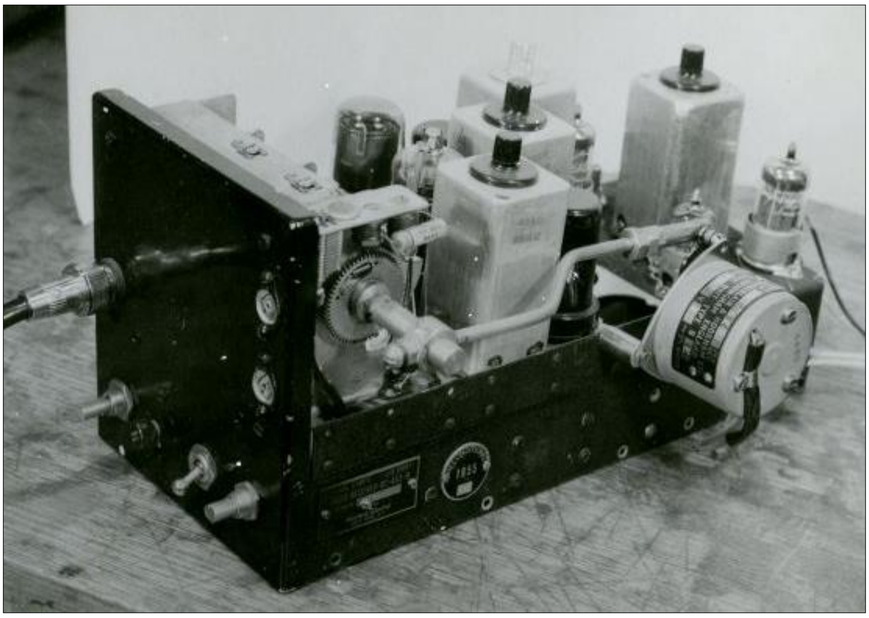


Figure 7: A receiver with a mechanical sweep, used at Richmond. The motor that was used to drive the motions of the rotor for the variable capacitor can be seen at right (after Bessell, 1963).

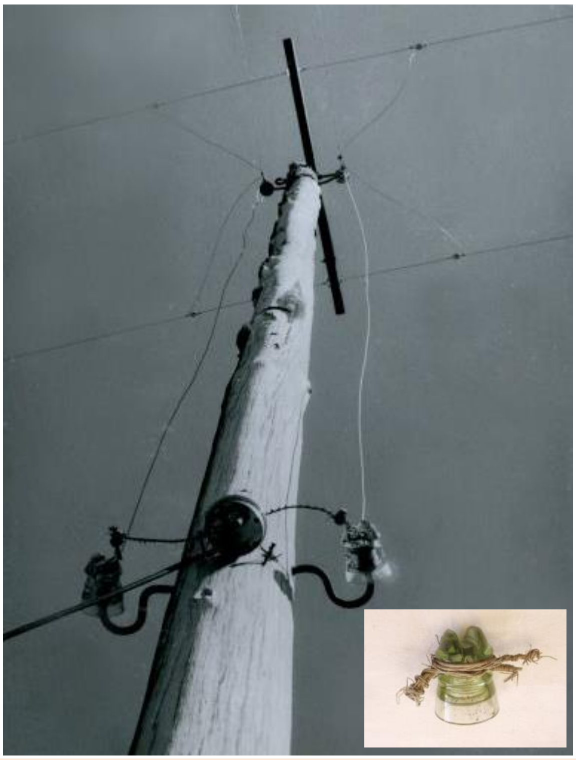


Figure 8: One of the telegraph poles at Richmond, with a close up of an insulator shown in the inset photograph (after Bessell, 1963).

Bessell (ibid.) also commented that because of the low frequencies at which he was working there were atmospheric spikes—which were to be expected. These were countered by having a minimum reader circuit on the input, which revealed any steady or slowly varying background.

This use of a 'minimum reader' method, often in combination with a suitable time constant to avoid the problem of atmospherics, was commonly used by low frequency researchers and was superior to simply identifying an apparently-empty channel and remaining at that exact wavelength.

4 THE OBSERVATIONS

Observations at Richmond were conducted over the winter and spring of both 1962 and 1963, at the three frequencies 2.35 MHz (July-October 1962 and June-October 1963); 1.55 MHz (July to October 1962, and June to October 1963); and

Figure 9: Some artefacts retrieved from the ground at the Richmond site in 2016 (Photograph: M. George).

1.03 MHz (late July to late August 1962). There also is evidence (Ellis and Hamilton, 1964) that some results at ~1.66 MHz were obtained during 1963; Bessell (1963) referred to some observations at this frequency in that year even though no details are presented.

Observations were carried out without phasing of the dipoles, resulting in the peak sensitivity being in the vertical direction toward declination −42° for all measurements. The receiver swept a bandwidth of 10 kHz each second, using the mechanical apparatus described in Section 3.

As would be expected, the 2.35 MHz observavations were the most successful. Bessell (ibid.) commented that 78 records were obtained in 1962 and 20 in 1963, but in 1963 only five nights produced observations that were "… useable for absolute measurement." At 1.55 MHz, 61 records were obtained in 1962 and 75 in 1963, but only 12 in 1963 were 'acceptable'. At 1.03 MHz, 31 records were obtained in 1962, but Bessell (ibid.) described these as "… very poor."

The 1.55 MHz observations were the only results presented graphically in Bessell's thesis (see Figure 10), where just three nights of observations are included: 22 July, 6 August and 31 August.

It is unclear whether these graphically-reproduced records were made in 1962 or in 1963, but it is highly likely that these were all 1962 observations, as Bessell (Ibid.) commented:

> The 1963 observations were affected by unexpected sunspots (~79 in July equal to solar max). These interfered with all observations but mainly at 1.5 Mc/s. Of 75 records obtained only 12 were taken as being good enough, however the profiles matched with the 1962 ones.

This comment is interesting, as it conflicts with records of sunspot numbers (see, e.g., Meeus, 1983; NASA Website, 2016) which, although they show a slight resurgence in solar activity during parts of 1963, indicate the sunspot numbers to have been only about 25% that of a typical solar maximum. However, the data show only the mean for the month, and it is possible that the figure may have been unusually high for part of July.

Bessell (ibid.) also made comments about the state of the ionosphere, mentioning that

> During July 1962 there appeared to be about six clear hours. During August 1962 there were two records unaffected for 4 hours and there were 7 others with one or more clear hours just before dawn. During September 1962 the ionosphere had effectively closed up.

These varying ionospheric conditions may explain the cut-off levels at different right ascen-

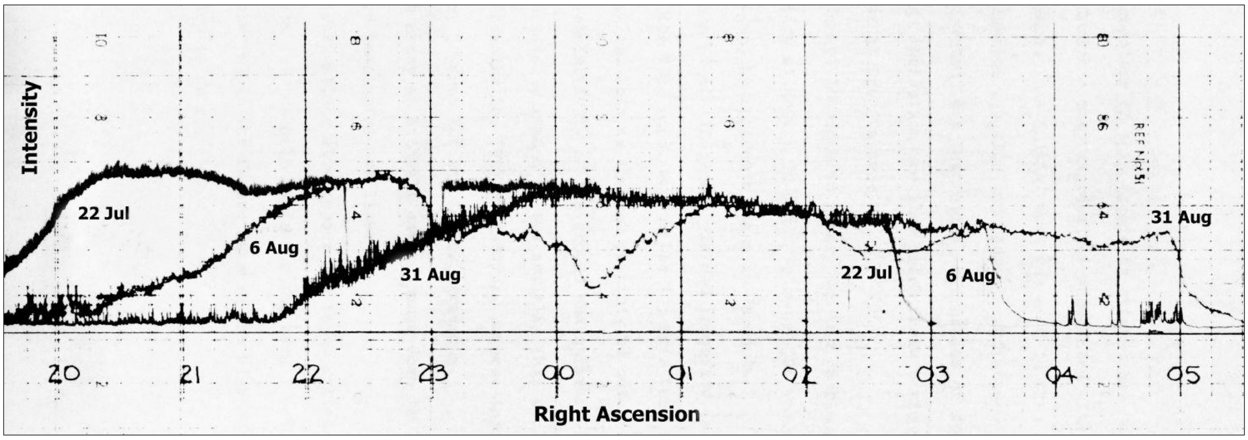


Figure 10: 1.55 MHz observations made by Bessell (adapted from a diagram in Bessell, 1963).

sions which are a pronounced feature of Figure 10.

The observations, including those at 9.8 and 4.8 MHz made at Llanherne in 1961 (see Waterworth, 1961), were combined in a paper in which the dependence of intensity on frequency below 10 MHz was plotted and discussed (Ellis et al., 1962). These results were compared with those obtained in 1955 by Reber and Ellis (1956) at Cambridge, and showed good agreement with these earlier observations.

Comparison between the 1961–1962 observations and those of the late 1950s, however, suggested that the former revealed a steeper drop in intensity than expected near the lower end of the frequency range, below 2 MHz. The authors attributed this to the earlier observations being made under "… rather unusual ionospheric conditions." (Ellis et al., 1962: 1079). They also noted that the highest maximum intensity occurred around 19h right ascension and the lowest maximum around 4h right ascension, with the maximum around 19h being around 7 MHz and around 4h being around 5 MHz. These differences were attributed to absorption of the radiation in interstellar ionised gas (Ellis et al., 1962), which was discussed at considerable length by Cambridge University's Fred Hoyle (1915–2001) and Ellis in an important paper published the following year.[8]

The Hoyle and Ellis (1963) paper derived equations relating to the radiation from the galactic disc and halo, respectively, and showed that at high galactic latitudes the frequency of maximum intensity was expected to be a factor of 1.45 higher for disc radiation when compared with halo radiation, closely matching the factor of 1.4 that was observed.[9]

5 DISCUSSION

Although Bessell's research followed by several years the initial observations made by Reber and Ellis at Cambridge at similar frequencies, the Richmond effort nevertheless represented quite serious early work at frequencies in the 1–2 MHz range.

Despite this, the importance of the Richmond site is not widely recognised. Perhaps this is because Mike Bessell was the only researcher who used this site, and the arrays only were utilised during 1962 and 1963. The 'field station' clearly had fallen into disarray by 1965 with many poles having been removed or fallen, while the nearby array at Penna, operating firstly at 4.7 MHz and later 10 MHz, continued to operate until 1967.

Although Bessell (ibid.) comments that the losses due to the ground were not significant, a major problem with low frequency dipole arrays is that with decreasing frequencies it becomes increasingly difficult to avoid significant losses caused by inadequate height above the ground plane. At Richmond, the dipoles were supported only 7 metres (23 feet) above the ground, whereas the ideal height of one-quarter of a wavelength would see them placed at heights of 32, 48 and 73 metres, in decreasing order of frequency.[10] Because the received power factor is the square of this quantity, the loss was considerable. Bessell calculated these losses, including losses in the feeder lines, to be 15.7 dB at 2.35 MHz and 14.8 dB at 1.50 MHz.

Could the Richmond array, rather than being allowed to fall into disuse, have been utilised to produce further results, thus providing improved definition of the intensity-frequency curve? We consider that the reasons for this not happening are likely to have been a combination of the increased efforts at the much larger array at Penna, and the difficulties of observing at such low frequencies, even at time close to solar minimum. Bessell (1963) also commented:

> The narrow beam array at Bothwell can be tuned down to 1.5 Mc/s and this will produce more meaningful profiles. The satellite observations also appear now to be reliable and these should provide good data for the halo region in the band 1-10 Mc/s.

The Bothwell array, however, produced results only at 2.085 MHz (Reber, 1968).

6. CONCLUDING REMARKS

The results at Richmond produced important points at the low frequency end of the intensity-frequency curve and served to clarify the dependence of the former on the latter, showing that the intensity dropped off more rapidly than had been suggested by the 1955 observations (see Reber and Ellis, 1956).

Although the Richmond arrays were operating for a relatively short time, they played an important role in the progress of low frequency radio astronomy in Tasmania, which blossomed in the 1960s under the leadership of Graeme Ellis.

This was not the only time that observations would be carried out in Tasmania at frequencies <2 MHz; successful 1.6 MHz work was undertaken at Llanherne in 1985 and 1986 (Ellis and Mendillo, 1987). However, the results from Richmond certainly contributed to the study of the intensity-frequency relationship, improving on existing knowledge of the relationship at these very low frequencies and even assisting in the interpretation of Reber and Ellis' 1955 results.

Meanwhile, it is interesting that when he enrolled for a Ph.D. Mike Bessell chose to pursue research in optical astronomy rather than radio astronomy, even though it is likely that he could have enrolled in and completed an ANU radio astronomy Ph.D. in association with the CSIRO's Division of Radiophysics, utilising the 64-m (210-ft) Parkes Radio Telescope.

7 END NOTES

1. Ellis also considered the use of an area of land near Bothwell, to the north of Hobart. However, this site ended up being used by Reber instead. The Bothwell field station will be discussed in a future paper in this series.
2. This is the sixth paper in a series, all published in this journal, which documents the early development of low frequency radio astronomy in Australia. The first two papers presented overviews of CSIRO initiatives near Sydney and Tasmanian research (Orchiston et al., 2015a; George et al., 2015a respectively), and were followed by three detailed case studies. These examined the Cambridge field station near Hobart (George et al., 2015b), the Hornsby Valley field station near Sydney (Orchiston et al., 2015b) and the Kempton field station in Tasmania (George et al., 2015c).
3. Historical studies of this type can often be frustrating because research papers only mention approximate locations of the observing sites. Thus, 'Hobart' has been used in reference to at least three distinct sites of antenna arrays (Llanherne, Penna and Richmond), the first two of which will be described in future papers in this series. The precise location of the observations at 2.35, 1.55, and 1.03 MHz discussed in this paper was discovered through personal communications with Elizabeth Ellis, Mike Bessell and Ben Jones, and finally was confirmed by the aerial photographs taken in 1965.
4. 'Telegraph Pole' is a term used to describe a wooden pole used to carry overhead cables. The term dates from the use of the telegraph system in Australia. It is still in occasional use to describe poles that carry cables supplying electricity, even though the telegraph system no longer exists.
5. The Hydro-Electric Commission was the name given in 1929 by the State Government to the former Hydro-Electric Department. It was a Government Commission charged with the operation of hydro-electric power stations and the construction of their associated dams. It is now called Hydro Tasmania.
6. Gordon Gowland and Kevin Parker both began working at the University of Tasmania in 1961, and were responsible for some of the construction and many of the technical installations for the University's low frequency radio astronomy arrays.
7. A 'variable capacitor', of the type used with these arrays, consists of two sets of parallel closely-spaced plates, each normally forming a semicircle, which mesh together. One is rotatable, thereby changing the overlapping area of the two sets, and thereby changing the capacitance of the device. It is sometimes called a 'tuning capacitor', because of its use to change the resonant frequency of a circuit.
8. This paper resulted from a visit that Hoyle made to Tasmania, where he met Ellis and they discussed the University of Tasmania's low frequency radio astronomy program (see Delbourgo and McCulloch, 2013).
9. Hoyle and Ellis' estimate of the mass of our galaxy, 5×10^8 solar masses, is about three orders of magnitude less than the currently-accepted value (excluding dark matter). However, this does not sensibly affect the explanation of the relative frequencies of maximum radiation.
10. The received energy is maximised when

    $\sin(2\pi h/\lambda) = 1$

    where h is the height of the dipole and λ is the wavelength.

8 ACKNOWLEDGEMENTS

We wish to thank Michael Bessell, Elizabeth Ellis, Susan Blackburn, Gordon Gowland, Philip Hamilton, Ben and Hana Jones, Peter McCulloch, Kevin Parker, the late Michael Waterworth for their assistance, and Peter Robertson for bringing information in Note 8 to our attention. We also thank the Department of Primary Industries, Parks, Water & Environment (Tasmania) for kindly supplying the 1965 aerial photograph that was used to generate Figures 4 and 5.

9 REFERENCES

Bessel, M., 1963. *Low Frequency Galactic Radio Emission.* B.Sc. Honours Thesis, University of Tasmania, Hobart.

Bessell, M., 2005. Standard photometric systems. *Annual Review of Astronomy and Astrophysics*, 43, 293–336.

Ellis, G.R.A., and Newstead, G., 1957. Discrete sources of cosmic radio noise at 18.3 and 10.5 Mc/s. *Journal of Atmospheric and Terrestrial Physics*, 10, 185–189.

Ellis, G.R.A., Waterworth, M. and Bessell, M., 1962. Spectrum of the galactic radiation between 10 Mc/s and 1.5 Mc/s. *Nature*, 196, 1079.

Ellis, G.R.A., and Hamilton, P., 1964. Absorption of radio waves in the galaxy. *Nature*, 204, 272–273.

Ellis, G.R.A., and Mendillo, M., 1987. A 1.6 MHz survey of the galactic background radiation. *Australian Journal of Physics*, 40, 705–708.

George, M., Orchiston, W., Slee, B., and Wielebinski, R., 2015a. The history of early low frequency radio astronomy in Australia. 2: Tasmania. *Journal of Astronomical History and Heritage*, 18, 14–22.

George, M., Orchiston, W., Slee, B., and Wielebinski, R., 2015b. The history of early low frequency radio astronomy in Australia. 3: Ellis, Reber and the Cambridge field station near Hobart. *Journal of Astronomical History and Heritage*, 18, 177–189.

George, M., Orchiston, W., Wielebinski, R., and Slee, B., 2015c. The history of early low frequency radio astronomy in Australia. 5: Reber and the Kempton field station in Tasmania. *Journal of Astronomical History and Heritage*, 18, 312–324.

Hoyle, F., and Ellis, G.R.A., 1963. On the existence of an ionized layer about the galactic plane. *Australian Journal of Physics*, 16, 1–7.

McCulloch, P., and Delbourgo, R., 2013. Graeme Reade Anthony ('Bill') Ellis 1921–2011. *Historical Records of Australian Science,* 24, 96–108. [Obituary. A pioneer in the area of low-frequency radio observations.]

Meeus, J., 1983. *Astronomical Tables of the Sun, Moon and Planets*. ISBN 0-943396-02-6. Richmond, Willman-Bell.

NASA Website, 2016.
http://solarscience.msfc.nasa.gov/greenwch/SN_m_tot_V2.0.txt. Retreived May 2016.

Orchiston, W., George, M., Slee, B., and Wielebinski, R., 2015a. The history of early low frequency radio astronomy in Australia. 1: The CSIRO Division of Radiophysics. *Journal of Astronomical History and Heritage*, 18, 3–13.

Orchiston, W., Slee, B., George, M., and Wielebinski, R., 2015b. The history of early low frequency radio astronomy in Australia. 4: Kerr, Shain, Higgins and the Hornsby Valley field station near Sydney. *Journal of Astronomical History and Heritage*, 18, 285–311.

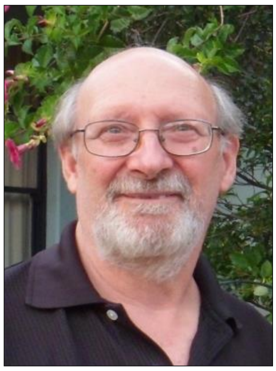
Reber, G., and Ellis, G.R.A., 1956. Cosmic radio-frequency radiation near one megacycle. *Journal of Geophysical Research*, 61, 1–10.

Reber, G., 1968. Cosmic static at 144 meters wavelength. *Journal of the Franklin Institute*, 285, 1–12.

Waterworth, M., 1961. *Cosmic Radio Emission at 4.85 Mc/s and 9.7 Mc/s.* B.Sc. Honours Thesis, University of Tasmania, Hobart.

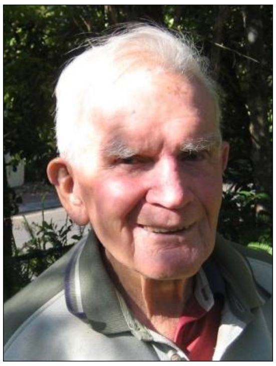
Martin George is the Collections and Research Manager at the Queen Victoria Museum and Art Gallery in Launceston, Tasmania, and also is responsible for the Museum's planetarium and astronomy collections. He is a former President of the International Planetarium Society. Martin has a special research interest in the history of radio astronomy, and is completing a part-time Ph.D. on the development of low frequency radio astronomy in Tasmania through the University of Southern Queensland, supervised by Professors Wayne Orchiston and Richard Wielebinski (and originally also by Professor Bruce Slee). Martin is the Administrator of the Grote Reber Medal for Radio Astronomy, and is a member of the IAU Working Group on Historic Radio Astronomy.

Professor Wayne Orchiston was born in New Zealand in 1943 and works as a Senior Researcher at the National Astronomical Research Institute of Thailand and is an Adjunct Professor of Astronomy at the University of Southern Queensland in Toowoomba, Australia. In the 1960s Wayne worked as a Technical Assistant in the CSIRO's Division of Radiophysics in Sydney, and forty years later joined its successor, the Australia Telescope National Facility, as its Archivist and Historian. He has a special interest in the history of radio astronomy, and in 2003 was founding Chairman of the IAU Working Group on Historic Radio Astronomy. He has supervised six Ph.D. or Masters theses on historic radio astronomy, and has published papers on early radio astronomy in Australia, England, France, Japan, New Zealand and the USA. He also has published extensively on the history of meteoritics, historic transits of Venus and solar eclipses, historic telescopes and observatories, and the history of cometary and asteroidal astronomy. Early in 2016 Springer published his latest book, *Exploring the History of*



New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits (733 pp.). He is the Vice-President of IAU Commission C3 (History of Astronomy), and is a co-founder and the current Editor of the *Journal of Astronomical History and Heritage*. In 2013 the IAU named minor planet 48471 Orchiston after him.

Dr Bruce Slee* was born in Adelaide, Australia, in 1924 and is one of the pioneers of Australian radio astronomy. Since he independently detected solar radio emission during WWII he has carried out wide-ranging research, first as a member of the CSIRO's Division of Radiophysics, and then through its successor, the Australia Telescope National Facility. After working with John Bolton and Gordon Stanley on the first discrete sources at Dover Heights, Bruce moved to the Fleurs field station and researched discrete sources with Bernie Mills using the Mills



Cross, and radio emission from flare stars with the Shain Cross and the 64-m Parkes Radio Telescope. He also used the Shain Cross and a number of antennas at remote sites to investigate Jovian decametric emission. With the commissioning of the Parkes Radio Telescope he began a wide-ranging program that focussed on discrete sources and radio emission from various types of active stars. He also used the Culgoora Circular Array (Culgoora Radioheliograph) for non-solar research, with emphasis on pulsars, source surveys and clusters of galaxies, and continued some of these projects using the Australia Telescope Compact Array. Over the past two decades, he also has written many papers on the history of Australian radio astronomy, and has supervised a number of Ph.D. students who were researching the history of radio astronomy.

Professor Richard Wielebinski was born in Poland in 1936, and moved with his parents to Hobart, Tasmania, while still a teenager. Richard completed B.E. (Hons.) and M.Eng.Sc. degrees at the University of Tasmania. In his student days he met Grote Reber and was involved in the construction of a low frequency array at Kempton. After working for the Postmaster General's Department in Hobart he joined Ryle's radio astronomy group at the Cavendish Laboratory, Cambridge, and completed a Ph.D. in 1963 on polarised galactic radio emission. From 1963 to 1969 Richard worked with Professor W.N. (Chris) Christiansen in the Department of Electrical Engineering at the University of Sydney, studying galactic emission with the Fleurs Synthesis Telescope and the

64-m Parkes Radio Telescope. He also was involved in early Australian pulsar research using the Molonglo Cross. In 1970 Richard was appointed Director of the Max-Planck-Institute für Radioastronomie in Bonn, where he was responsible for the instrumentation of the 100-m radio telescope at Effelsberg. In addition, he built up a research group that became involved in mapping the sky in the radio continuum, studying the magnetic fields of galaxies, and pulsar research. Further developments were the French-German-Spanish institute for mm-wave astronomy (IRAM), and co-operation with the Steward Observatory, University of Arizona, on the Heinrich-Hertz Telescope Project. Richard holds Honorary Professorships in Bonn, Beijing and at the University of Southern Queensland. He is a member of several academies, and has been awarded honorary doctorates by three universities. After retiring in 2004 he became involved in history of radio astronomy research, and is currently the Chairman of the IAU Working Group on Historic Radio Astronomy.

* It is with great sadness that we report that our close friend and collaborator, Bruce Slee, died on 18 August 2016, just eight days after his 92nd birthday and one day after the very successful SleeFest Workshop was held in Sydney to commemorate his amazing 70-year contribution to radio astronomy. At that meeting I reported that the IAU recently named minor planet 9391 Slee in his honour.

Wayne Orchiston