A unique individual —

Radio astronomy's original pioneer — Grote Reber

by Roger Harrison VK2ZTB

I was surprised to learn last year that Grote Reber, virtually the 'founder' of the science of radio astronomy, lived and worked in Tasmania. I had the rare opportunity to meet him in June and to talk about his work.

THE SCIENCE of radio astronomy is not fifty years old, yet it has had a more profound influence on our knowledge of the universe and the fundamental physics of nature than has Galileo's invention of the optical telescope.

In the late 1920s, a young engineer from Bell Telephone Laboratories, Karl Jansky, was set the task of investigating the cause of interferences on transoceanic telephone links. Between 1929 and 1932, with his "merry-go-round" antenna, he made a series of observations. Along the way he detected a source of noise that appeared to be fixed in space and which came from the centre of our galaxy. Upon the completion of his research and the publication of a scientific paper, Karl Jansky was transferred to other work. He did not pursue the matter further and the significance of his discoveries was not realised by the astronomers of his day.

Some years later Grote Reber was looking for something "a little more exciting" to extend his hobby of amateur radio. He had come to know Karl Jansky, who suggested to the 22 year old Reber that he "look to the heavens".

Reber designed and built the world's first 'radio telescope', a 10m diameter parabolic dish, constructed of wood and galvanised iron sheeting. He designed and prefabricated every part prior to assembling the dish in his back garden. That dish is preserved in the Smithsonian Institute's museum in the US.

Grote Reber first attempted observations near 3000 MHz but results were inconclusive, largely owing to the limitations of the technology of the time. He subsequently modified his equipment for use on 900 MHz and later 160 MHz, eventually succeeding in making what was the first 'map' of the sky ever to be completed using radiation other than that of the visible spectrum. He also detected and described radio emissions from the sun.

The science of radio astronomy was born.

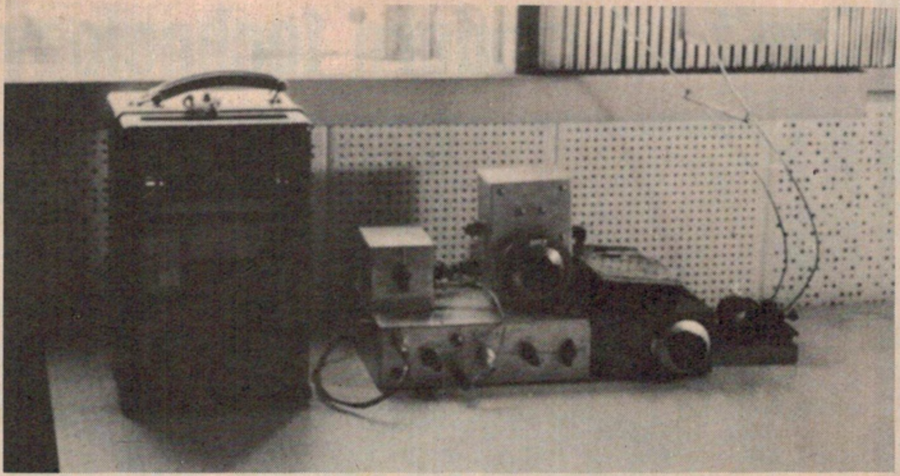
Reber's observations were taken up and extended by others following publication of his results, but work was interrupted by World War II. Following the war, interest in radio astronomy burgeoned, propelled by the explosion in technology as a result of the war effort. Whilst most workers in the young science headed for higher and higher frequencies, Grote Reber thought he might go in the other direction. In the late 1940s and early 50s, it was thought that the lowest possible observation frequency was about 10 MHz, a limit set by the 'opacity' of the ionosphere — the region of ionised gases extending from about 100 km to about 800 km that encircles the earth and refracts radio waves, permitting communications over long distances on the 'shortwave' bands between 1 MHz and 30 MHz.

Reber was interested in what the sky 'looked like' at frequencies below 3 MHz, but many of the "... experts of the day, self-appointed and otherwise ..." said it would be "impossible" to make observations at these frequencies. Firstly, the ionosphere 'got in the way' like an invisible curtain or shroud, and secondly interference from man-made signals, along with atmospheric noise, would mask even strong cosmic signals.

Fortunately, Reber, having a determined nature (a "cussed streak", as he puts it) took no notice of "... these Cassandras ..." and set out to thoroughly research the problems of making observations below 3 MHz.

He sought to find a 'window' through the ionosphere, where the vertical incidence critical frequency (that frequency where a signal beamed directly overhead will pass through the ionosphere) dropped below 1 MHz on occasions. He made a search of the available ionospheric data (ionospheric research was then itself still a fledgling science) and found several regions around the world where the ionosphere behaved as required. However, there were a few restraints. He had to choose an area that was remote, to be away from sources of man-made noise and interference, but in a 'civilised' country so that he could avoid any political problems and build a suitable antenna without incurring large transport and construction costs. Climate was another factor in Reber's choice.

He chose the highlands of Tasmania.



Current receiving equipment is all solid state. The antenna feedline can be seen to the right, chart recorder on the left.

Meeting the man

I was introduced to Grote Reber on a cold, windswept afternoon last June. It was the shortest day of the year and I had driven from Launceston with a friend of Grote, Jim Davis, VK7NOW, and Jim's friend Bill Carter, VK7AK, who knew the mountain roads like the back of his weatherbeaten hands.

We arrived at the house Grote rents from a neighbour to find him sawing timber for the 'solar house' he's working on — of which more later. We discussed the project briefly and then drove to the radio astronomy installation just a handful of kilometres away. The casual observer, if he noticed at all, would no doubt be mildly curious about the lines of stark, grey poles set up some distance from the road on an expansive tract of flat land but there is little to give away their purpose. The entrance to the 'observatory' is unprepossessing and unmarked — just another paddock gate. A 3 km long dirt road, broken by several cattle grids, leads to the small hut located in the 'centre' of the antenna array. An ingenious sign at the first cattle grid says "Warning: Radio Astronomy". Grote says it's quite effective in "... keeping out the idly curious".

At the hut, Grote Reber gave us a description of his work and the equipment he uses and has used. He talks in a clear, well-reasoned manner and his mid-west American accent is still strong. It's a fascinating story that he tells.

What and how

Reber came to Australia in the early '50s and searched out a suitable site for his antenna. This was to be an array covering some 400 acres, consisting of 128 dipoles centred on a frequency near 2 MHz!

Construction commenced in 1953 and Reber began observations the following year. The whole structure, supported on a series of locally-felled eucalypt hardwood poles each some 20m high, was erected on a level area on a farm located in a natural depression in the mountains east of Lake St. Clair.

The entire array was constructed on a "shoe string" budget, on money obtained from a research grant, with the assistance of local people. A great deal of effort was made to ensure that the structure would last 20 years or more. The poles are clearly still in good condition and should exceed the design life by a wide margin.

The 128-dipole antenna array is an 'aperture synthesis' type and has a beamwidth of 7°! In its original configuration the beam pattern could be 'steered' electronically by changing the phasing on the network of antenna feeders. While it sounds simple enough, the job had to be done by physically moving a series of clip-on shorting straps on the open-wire feedlines. This task takes two men about half a day!

The array could be set to 'view' a particular sector of the sky, the rotation of the earth 'sweeping' the beam across the selected path. The beam can be steered in elevation from near the northern horizon, through the zenith ('straight up') and almost to the southern horizon.

Each dipole in the array has been constructed to cover the range between about 1800 kHz and 2000 kHz. This is done using a cunning technique involving the antenna length and a specially-constructed tuned matching transformer that provides a response similar to a double-tuned circuit.

Each dipole is cut a little 'short' for the desired operating frequency and its feedpoint exhibits a capacitive reactance along with the antenna's characteristic radiation resistance. The dipole feedpoint is tapped onto a large, high-Q inductor that resonates near 2 MHz with its own self-capacitance and the capacitive reactance of the antenna. Inside this coil, and thus tightly coupled to it, is another which is tuned by a variable capacitor. The open-wire feedline to the rest of the system is tapped onto this coil to provide the desired impedance match. The whole assembly forms an over-coupled transformer which exhibits the classic 'double-humped' wideband response. Grote carefully designed this transformer arrangement to have minimum loss (about 0.5 dB) and an acceptably 'flat' response (2 dB, or less, variation) across the band of interest.

128 of these assemblies were constructed, each housed in a weatherproof box made of galvanised iron sheet with ceramic feedthrough insulators for the feedline connections. Most were disassembled from the antenna system and stored some years ago.

Grote Reber has a self-confessed "obsession with measuring things". After all, isn't that what radio astronomy's all about? True to form, he *measured* the variation in ground resistance beneath his antenna array, plotted equal-resistance contours and calculated the overall ground resistance.

The receiver and recording system are housed in a small hut located near the centre of the large array. Power is obtained from batteries, which was some problem with the original receiver system as it used valves! About 18 years ago Grote constructed a solid-state receiver which is still in use. It is considerably smaller than the old valve 'monster' which took up the whole of the small table provided for the purpose. The receiver is tunable so that an observation frequency can be selected which is clear of ground wave propagated (and some ionospherically propagated) signals. The receiver only has four stages (plus an audio stage for headphone use) and includes several selectable bandwidths and integration times on the detector output. Hooked ▶

onto the output is a simple spring-driven chart recorder used to collect the data. Grote also uses an outboard BFO to detect the presence of weak signals that may interfere with his measurements.

If you tune around 2 MHz of an evening you'll find the region 'alive' with signals. How does Grote Reber hear the stars? It works like this: When the critical frequency of the ionosphere above his antenna dips below 2 MHz, all those signals that usually 'bounce' off the ionosphere no longer have any ionosphere in the region to 'bounce' off. The ionospheric curtain 'withdraws', all those interfering signals head off into space and the cosmic noise 'comes in'. It sounds like the 'hiss' of a radio receiver not tuned to any signals. Grote Reber estimates the cosmic noise to be around 20 microvolts at the antenna terminals of his receiver.

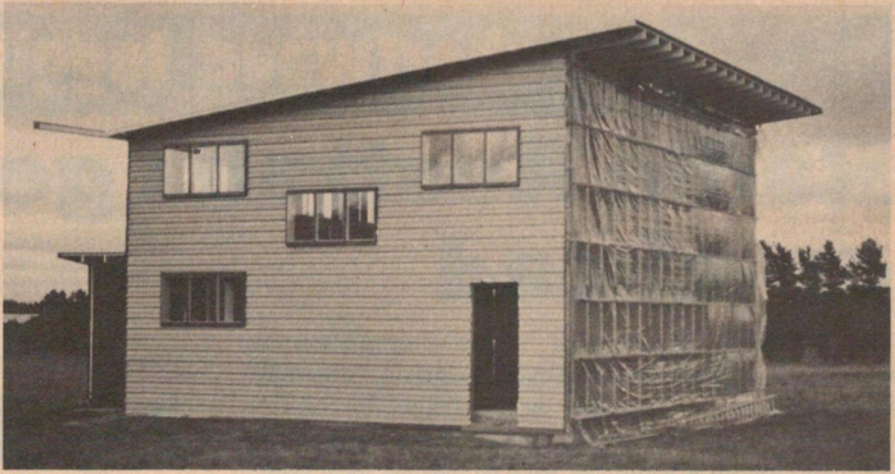
The ionosphere will only 'open up' at certain times, however. These times are greatly influenced by the diurnal (daily), and seasonal cycles of ionospheric activity and the longer term influence of the solar activity cycle which has 'peaks' and 'troughs' roughly spaced at 11 year intervals.

During a trough, or minimum, in solar activity, the ionospheric critical frequencies are much lower than during a peak, or maximum. As a consequence, Grote Reber can only make his observations during a solar minimum and suitable conditions generally last only 18 months or less. To make matters worse, the critical frequencies are only low enough during the winter months and at night — generally between 11 p.m. and 3 a.m. or so!

Grote made his first observations during the winter of 1954, a solar minimum year. He then had to wait until 1963-64 for the next solar minimum! From data compiled during those observing years, he built up a 'map' of the sky at a wavelength of 150 metres — quite an achievement, since the longest wavelength observations to date had been at a wavelength around 10 metres (about 30 MHz). His results were published in The Journal of the Franklin Institute (USA) in 1968. He last made observations during the solar minimum of 1975-76 and he's currently waiting for the next solar minimum (due around 1986 or so).

In the meantime, a curious limitation has arisen. It seems that long term solar activity is reducing the period over which he can make observations and the number of days during that period when the critical frequencies are low enough. The 'smoothed sunspot number' (a statistical measure of solar activity) during the 1954 minimum was as low as two but during the minimum just past it was greater than 10, with a consequent general increase in the ionospheric critical frequencies.

Quite undaunted, having proved the "Cassandras" conclusively *wrong*, Grote is preparing for the next minimum and another series of observations during those long, cold Tasmanian winter nights.



The 'solar house' Grote Reber is constructing in Tasmania. He designed and prefabricated the complete framework from oregon he bought direct from a mill in Oregon, USA, and imported here.

Other projects

The radio astronomy observations at 150 metres wavelength don't occupy all of Grote's time. He is employed part of the time by a local division of the CSIRO in a field quite removed from radio astronomy. He's also engaged in constructing and researching an electric car — this project is currently in America undergoing wind tunnel trials; he spends part of his time each year in the US. Apart from that, he is currently engaged in constructing a 'solar-powered' house which was partly completed when we saw it on our visit. This project is typical of his thorough, carefully thought-out approach to everything he does. The frame is timber and was completely designed and prefabricated prior to erection. He sought a local supply of oregon for the frame but found the timber offered of too poor a quality. On a trip to America last year he bought a container load of oregon and had it shipped to his Tasmanian address! Not only did he get the quality of timber he wanted, but he saved a considerable amount of money in the process.

The house is a two-storey structure with a slanted roof and the largest external wall facing due north. This wall is made up of 102 'cells'. About 12 are used for windows; the rest collect heat from the sun, raising the temperature of the air in the cell. This heated air is drawn by fans down into a deep basement which takes up the entire area under the house. This basement is to be filled with rocks, each about the size of an egg. The heat will be stored in these rocks during the day and during the night, heat will be obtained from the rocks by drawing air from the basement and circulating it through the house.

The eaves overhang the front of the house so that it is shaded during the middle of the day in summer, preventing the house from becoming overheated.

The outer cladding and the roof are of aluminium siding with internal reflective insulating sheet and asbestos batts. Grote has designed his house so that there will be no need for any heating or cooling system fuelled by that precious and increasingly expensive commodity — petroleum oil. Light and power will be obtained from the Tasmanian SEC grid — as it's hydro-electric power (and thus, ultimately, solar-derived) he figures that's fair enough.

The windows, though smaller than are fashionable, are designed to provide adequate natural lighting while minimising heat loss.

At a stage in life when most people have either retired or are rapidly approaching the end of an active working life, Grote Reber's pioneer attitude is as strong as ever and he continues to march forward, with well thought-out and carefully executed strides, where others merely 'dabble their toes' or turn away seeking easier paths. ●

Epilogue

It was at the suggestion of Jim Davis that I took the opportunity to meet Grote Reber who, I must confess, was one of the heroes of my youth. Jim arranged the meeting at *very* short notice and he and Bill Carter proved able navigators. I am indebted to both gentlemen.

For those interested in further reading on radio astronomy, 'Radio Astronomy for Amateurs' by Hey, obtainable from some technical bookshops makes good reading. The author wrote a series on 'Radio Astronomy for Amateurs' published in ETI between December 1971 and April 1973.