The antenna in the valley

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The foundations for the 100-meter radio telescope in the construction phase (1968). Credit: MPIfR

When Galileo Galilei turned his modest "spy glass" towards the stars in the summer of 1609, he opened up new skies. He observed things which no one had ever seen before: mountains and craters on the moon, the phases of Venus, individual stars of the Milky Way. Galileo Galilei had pushed the window into space wide open. He had no way of knowing that his telescope observed only a tiny octave in the cosmic keyboard of light, because the electromagnetic spectrum we receive from space stretches across twelve orders of magnitude: at one end are the high-energy gamma rays with wavelengths of 0.01 nanometres (one billionth of a meter); at the other, the radio region with wavelengths of several metres.

Karl Jansky opened up this radio window in the early 1930s. The

American engineer built a 30-metre monster from wood and wire on behalf of the Bell Phone telephone company and listened for interference signals in the short-wave band - and, lo and behold, a hiss actually got caught in Jansky's antenna: but not from an intergalactic radio broadcast by aliens, but from the centre of the Milky Way.

Today, researchers from the Max Planck Institute for Radio Astronomy use high-tech dishes to search for signals from the long-wave end of the electromagnetic spectrum. At the heart of the Bonn-based Institute is the antenna that was inaugurated in 1971 near Effelsberg in the Eifel Mountains – with a diameter of 100 metres it was, for decades, the largest fully steerable radio telescope in the world. (The American Greenbank telescope, with an effective diameter of slightly over 100 metres outranked it a few years ago.)

Compared to other European countries, radio astronomy got off to a late start in Germany. This was down to the technical restrictions which the occupying forces imposed on researchers as a consequence of the Second World War. It was only in the middle of the 1950s that a fully steerable antenna with 25-meter diameter was built on Stockert Hill north of Bad Münstereifel. At the same time, the Heinrich-Hertz Institute in Berlin-Adlershof built a 36-metre transit instrument that was intended for galactic research.

In 1962 the Denkschrift zur Lage der Astronomie (memorandum on the situation of astronomy) submitted a proposal to build a large-scale instrument for radio astronomy. Otto Hachenberg, Head of the Institute for Radio Astronomy at the University of Bonn, then started to plan an 80-metre telescope. The government of the Federal State of North Rhine-Westphalia funded the planning stage and preliminary work. The company Krupp provided a draft design which involved a flexible solution instead of a rigid steel construction so that the reflector's parabolic form was maintained as the telescope tilted. This made it possible to increase the antenna's diameter to 90 meters. In 1964 Hachenberg, together with his colleagues Friedrich Becker and Wolfgang Priester, submitted an application to the Volkswagen Foundation for funds to build this large-scale instrument.

At around the same time, the Foundation received a second application: Sebastian von Hoerner from Tübingen was planning a 160-meter reflector. Both projects were initially recognized as being worthy of support; however, the high operating costs of such instruments meant a suitable sponsoring organization had to be found. The Max Planck Society declared its willingness to create an appropriate institute. Thanks to the preliminary work which had already been done and the support of the State of North Rhine-Westphalia, the Max Planck Institute for Radio Astronomy (MPIfR) was established in Bonn. Otto Hachenberg was appointed Director.

As the plans for the Tübingen project had been abandoned, more funds were available for the project in Bonn. Calculations had shown that a surface with sufficient accuracy could also be achieved for a 100-meter reflector – and so it was decided to build this.

The search for a suitable location started in 1966. It was clear that only a valley which provided shielding against interfering radiation was an option. The final choice was a valley running north-south, close to the village of Effelsberg near Bad Münstereifel. Most of the 15.4 hectare site was just within the borders of the State of North Rhine-Westphalia.

The engineers had to tread completely new paths for the construction. They had to break with the conventional way of designing a reflector, as had been realized at the time with the Mark 1 telescope at Jodrell Bank, England, and the Parkes telescope in Australia. After all, the 100-metre dish was to have a surface accuracy of one millimetre. One team at Krupp achieved its aim of eventually producing a radially symmetric structure for the reflector. A separate tilting frame was to hold the reflector in the axial direction. This design allowed particularly simple computations of the elastic deformation as it was tilted.

The tilting frame and the focal support legs together formed an octahedron which was stabilized by a diagonal bracing structure in the interior. In addition, this construction also contained the counterweight for the reflector, which the tilting frame was to hold in the axial direction like an umbrella. Floating wheel drives with a rim gear on one arm of the octahedron were selected for the tilting movement. The base frame had four drives with 16 motors and 32 wheels for the azimuth drive, with a load of around 100 tonnes per wheel. A concrete ring was to bear the azimuth track with a diameter of 64 meters. Spaces for the power supply and workshops were provided in the foundations.

A 130-metre high crane had to be erected before the building of the steel construction could begin. Responsibility for the assembly and manufacturing work on site fell to the company MAN. A machine in a cabin at the edge of the assembly area was used to produce the complicated cuts of the tubes for the reflector. Step by step the reflector structure was welded together, until finally sector-shaped components were created. Larger constructional elements with rectangular cross-section, like the trestle structure of the telescope, were manufactured from steel plate in the Krupp workshops in Rheinhausen and transported to Effelsberg.

The on-site welding for the reflector had to be carried out with high precision. The angular accuracy with which the tubes were aligned and welded together was especially critical. Eventually the reflector sections were stacked up at the assembly area; some of them were already equipped with reflector panels on the ground. The assembly involved alternately mounting the sector components on opposite sides. This meant that the engineers had to ensure that the instrument could be driven in the azimuthal direction even during the early stages of assembling the telescope.

In 1970 the engineers mounted the reflector's last sector. A gap of only five millimetres showed the astonishing accuracy with which the steel construction had been built. The remaining panels could now be mounted. Finally, the reflector area was calibrated with the theodolite.

The scientists and engineers had equipped the telescope with complete computer control. This was intended to make it possible to align the antenna with an accuracy of better than ten arc seconds. The drive system came from AEG, the encoder for the telescope axes from the company Heidenhain. An ARGUS 500 system from the company Ferranti was selected as the process computer. The astronomical control programs were developed by the Institute, as were the receivers.

On April 23, 1971 the new radio telescope registered the first signals at a wavelength of eleven centimetres, and only a simple dipole was used in the primary focus. During the official opening on May 12, 1971 the antenna was fully operational with measurements of the radio continuum at a wavelength of 73 centimeters. Observations at 408 megahertz were carried out during the inauguration; they eventually led to the famous survey of the complete radio sky.

The Effelsberg 100-metre telescope has served two generations of radio astronomers and led to thousands of scientific publications. The careful maintenance of the instrument by the technical teams has ensured its continuous operation. In the course of the past 40 years, researchers and engineers have also continuously improved the system – particularly with regard to the reflector's surface accuracy. In 2006 the sub-reflector was finally replaced. The new reflector has an actively adjustable surface that allows further improvements to be made for observations from the secondary focus.

There is a long list of receivers which have been developed for both the primary focus and the secondary focus in order to cover all frequency bands of interest in the centimetre wavelength range. The Effelsberg telescope has even been used successfully at 86 gigahertz (three millimetre wavelength). Despite its age, it still numbers among the first-rate astronomical precision instruments.

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