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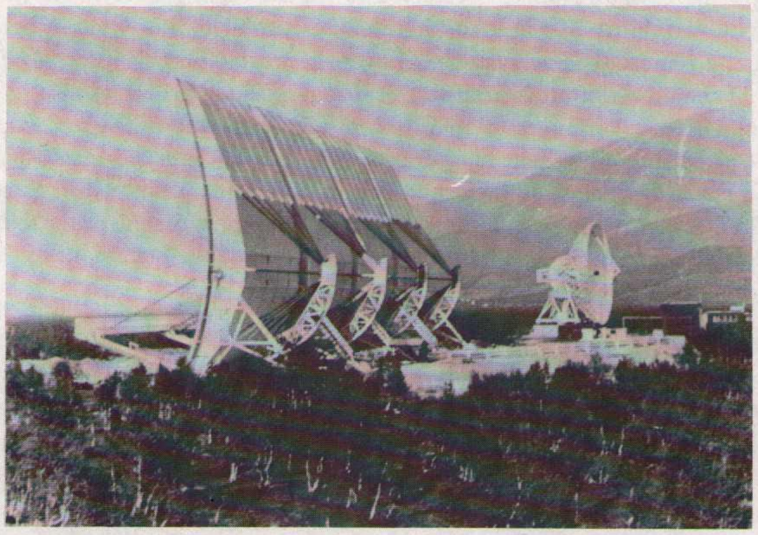
THE EISCAT INCOHERENT SCATTER RADARS

Radar was invented at the Radio Research Station, later re-named the Appleton Laboratory. Since the original experiment to detect an aircraft in February 1935, the laboratory has continued to be involved in a number of scientific studies using radar. The development of ever-more powerful transmitters and sensitive receivers has made it possible to probe the Earth's upper atmosphere, using the so-called "incoherent scatter" technique. The UK and France were the first two European nations to build permanent facilities which proved so effective that in 1975 an agreement was signed between the research Councils of the UK, France, West Germany, Norway, Sweden and Finland to build two powerful and sophisticated incoherent-scatter radars. One major objective was to study the effects of the aurora borealis (the 'northern lights') on the upper atmosphere and so the radars were situated in northern Scandinavia, where the aurora usually occurs. These radars were built by, and are now operated by, the EISCAT (European Incoherent SCATter) Scientific Association and have been producing unique scientific information since 1981.

What is EISCAT?

To study the full height range of the upper atmosphere, EISCAT requires two radar systems, one operating at UHF, one at VHF wavelengths. Figure 1 shows the antennae used at the site in Tromsø, Norway. The UHF system is unique in also having receivers in Kiruna, Sweden and Sodankylä, Finland, enabling determination of velocity vectors in three dimensions. These systems are completely computer- controlled, which allows some novel adaptive experiments and real-time and remote control.



The EISCAT site at Tromsø, Norway. On the right is one of the three 32-metre paraboloidal dish antennae of the UHF system. On the left is the huge cylindrical parabolic antenna of the VHF system.

The UHF radar operates on a number of frequencies near 933 MHz simultaneously and uses 32-metre diameter dishes which are fully steerable. The VHF radar uses frequencies near 224 MHz and has an antenna with a reflecting area of 40 by 120 meters (bigger than a football pitch!) and is mechanically steerable in elevation and electronically in azimuth. Both systems require these large antennae, extremely high transmitter powers (several megawatts) and ultra- sensitive receivers because the echoes from the atmosphere are so weak (a thousandth millionth millionth millionth of the transmitted power). It is equivalent to detecting a hard target the size of a penny at a range of 300 km.

What do we observe with EISCAT?

The signals received by the EISCAT radars come from ionised gases in the upper atmosphere between about 80 km and 1000 km altitude (the "ionosphere"). An ionised gas is called a "plasma" and this is the dominant state of matter - making up over 90% of the known matter in the universe. However, we live in a very peculiar part of the universe where plasmas are rare (lightning is one example) and large-scale plasmas cannot be generated in the laboratory. The ionosphere is the nearest large-scale plasma, giving us an opportunity to study the behaviour of this important state of matter.

The location of the EISCAT radars enables observation of the ionosphere at auroral latitudes where high-energy particles, many originally from the sun, stream into the atmosphere, causing it to emit light, rather like a TV screen. The aurora also results in heating and the production of plasma and influences the upper atmosphere and ionosphere globally. The continuous stream of particles from the sun is called the "solar wind", and this flow induces large-scale motion of plasma in the polar ionosphere as it streams around the Earth. By observing these ionospheric flows, EISCAT can be used to study dynamic processes which transfer energy, matter and momentum from the solar wind to the Earth's plasma environment. The EISCAT observations are often complemented by satellite observations, but have an important advantage in that they can distinguish spatial structures from temporal changes.

Why do we need EISCAT?

These scientific studies are not only important because of what we are learning about basic plasma physics and the interaction of the Earth with the solar wind; the ionosphere is also important for many operational systems, supporting long-distance HF communications (for example BBC World Service broadcasts) and enabling over-the-horizon radars to operate. The variability of the ionosphere causes problems for satellite communication, navigation and remote sensing systems all over the world and this is largely caused by the variability of the power input into the auroral zones. These processes also have significant implications for the planning and operation of all spacecraft which must operate within the Earth's plasma environment. In addition, heating of the upper atmosphere increases the drag on spacecraft, slowing them and causing them to spiral toward Earth. The data from EISCAT are providing vital information on these phenomena and are being used to test global models of the upper atmosphere which predict the behaviour of the ionosphere and its effects on operational systems.

Who uses EISCAT?

There are 12 research groups in Universities and Government Laboratories in the UK that use the EISCAT facilities. At RAL, we help groups to design and develop experiments which we run in intensive observing campaigns. The data are all stored on the project computer at RAL, which scientists access remotely to use the analysis algorithms that we are constantly developing to exploit the radars to the full. In addition, we carry out in-house research and the staff at the laboratory have been involved in many important discoveries concerning many different regions of space.

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