HOW TO BUILD YOUR OWN
RADIO TELESCOPE

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The radio telescope described in the book is very low power and therefore quite safe. The following precautions will ensure trouble-free operation:

1. Be aware that the antenna could be a hazard during a thunderstorm. You should disconnect the antenna during a thunderstorm, especially if it is outdoors

2. The solar storm radio telescope connects to a PC via a sound card. You can make use of an inexpensive external USB sound card if you don't want to connect anything directly to your PC

This book contains instructions, schematics, and computer programs for use in amateur radio telescope and computer interface projects. The content of the book is to be considered experimental only, and the authors make no claims as to the functionality of actual working models made from the instructions in this book. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities herein and to avoid all potential hazards. By following the instructions contained herein, the reader willingly assumes all risks in connection with such instructions.

Information contained in this book has been obtained from sources believed to be reliable. However the author does not guarantee the accuracy or completeness of the information contained herein, and the author shall not be responsible for any errors, omissions, or damages arising out of the use of this information.

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1. Why build a radio telescope?

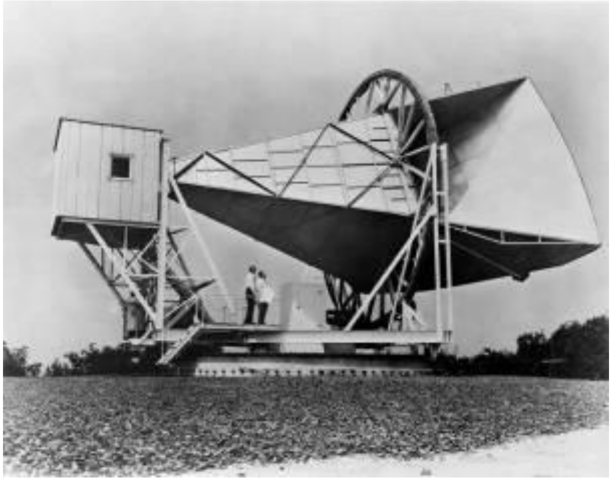

Fig 1.1. The experimental radio antenna that first detected the Cosmic Microwave Background Radiation in 1964 and won Arno Penzias and Robert Wilson the Nobel Prize.

Radio telescopes are critical for science and astronomy

It was an experimental radio antenna operating in New Jersey in 1964 that first detected the Cosmic Microwave Background Radiation. These microwaves, permeating through space in all directions, provided the original piece of experimental evidence for the theory of the Big Bang. The discoverers, Arno Penzias and Robert Wilson, received the Nobel Prize for Physics in 1978 for their finding.

This is just an example, of course, and whilst I'm not suggesting that your radio telescope project is going to lead to another Nobel Prize, I can guarantee that you are about to embark on an exciting journey of learning and discovery.

The sun is one of the most interesting subjects in radio astronomy

Sunspots and solar storms have some surprising effects here on earth. A study of agricultural markets in the 17th century showed that crop yields were higher and grain prices lower during years with high sunspot activity. It's still a mystery how this can happen, but sunspots must clearly influence the weather. A study of the Texas electricity market in recent years showed that solar storms reduced the efficiency of transformers in the electricity distribution grid and increased the price of electricity. Events can be more dramatic. On October 29th, 2003 the $450 million Japanese weather satellite Midori 2 was knocked permanently out of action by a solar storm, and on December 6th, 2006 the Global Positioning Satellite (GPS) system was disrupted by a solar storm.

Fig 1.2. The Midori 2 satellite before being disabled by a solar storm. Credit JAXA

In the next chapter I'll explain how the easy-to-build Solar Storm Radio Telescope that I describe in this book will let you monitor these events as they happen. You'll build up your own records of the solar storms that rage in the atmosphere above your home, and be able to share that information with others automatically over the internet. First let's look at some of the phenomena that are associated with solar storms.

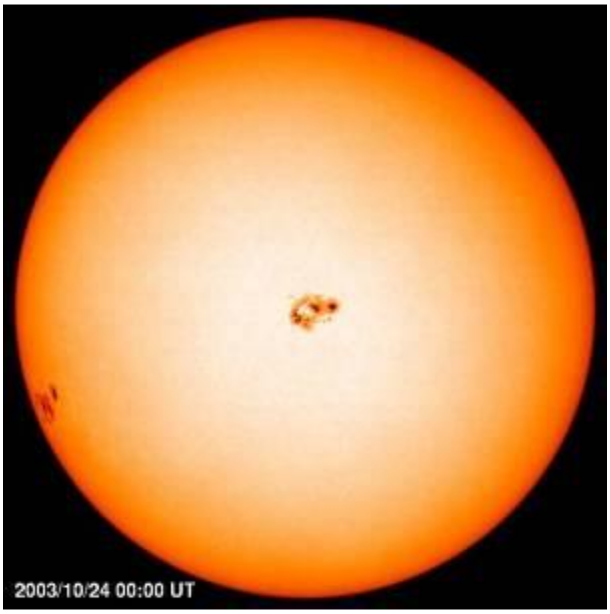

Fig 1.3. Sunspot are cooler regions that appear as dark blotches on the surface of the sun. Credit: SOHO

Sunspots
These are dark blotches on the surface of the sun that are cooler than their surroundings. They are caused by changes in the convection currents that bring the sun's heat from the interior to the surface.

Solar flares
Solar flares occur when magnetic field lines on the surface of the sun that have become compressed and distorted in the region of a sunspot suddenly reconnect with an explosive release of energy. Temperatures in the region reach more than 10 million Kelvin, and a burst of X-rays is shot out into space over a period of several minutes.

Usually solar flares pass away harmlessly into space, but occasionally the Earth will lie in the line of fire. It takes about 8 minutes for the X-rays to travel across the 150 million km between the Sun and the Earth. When the X-rays hit the ionized top layer of the Earth's atmosphere, the ionosphere, they create an electrical disturbance. The arrival of these powerful X-rays and the dynamism in the atmosphere that they create is known as a solar storm.

Fig 1.4. A solar flare driven by magnetic fields send X-rays into space. Credit NASA

Coronal mass ejections
These are sudden ejections of charged particles from the Sun's upper atmosphere (the corona). In a typical coronal mass ejection about 10 billion tons of matter (mainly electrons and protons) are fired away into space. Like solar flares, coronal mass ejections are likely caused by rapid reconfigurations of the magnetic field lines on the surface of the sun. Coronal mass ejections create solar storms when the Earth lies in the line of sight of the ejected particles.

Solar flares and coronal mass ejections are closely linked to the 11 year cycle of sunspot activity. At solar maximum there may be several solar flares or coronal mass ejections somewhere on the Sun every day. At solar minimum there may be weeks between these events.   The last solar maximum was in 2001. Scientists have predicted that the next solar cycle will start its build up in late 2007 or early 2008, and may be 30-50% more intense than the last cycle. So there's never been a better time to build a radio telescope.

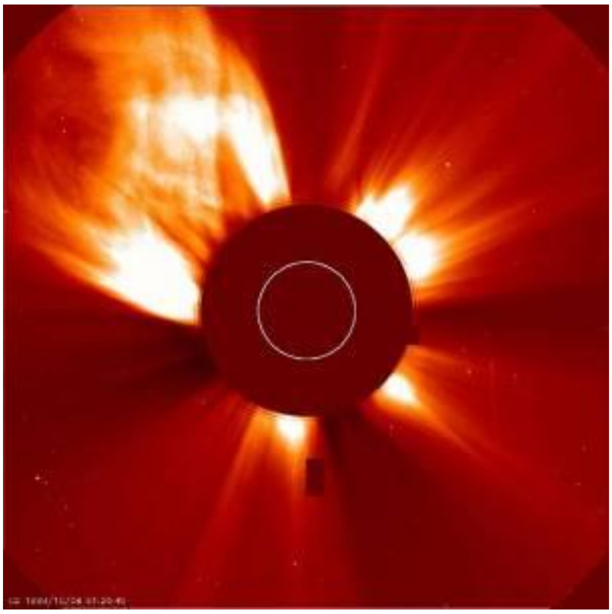

Fig 1.5. A coronal mass ejection. The disk of the Sun is obscured by the camera. Credit SOHO

2. Introducing the Solar Storm Radio Telescope (SSRT)

The SSRT monitors solar storms indirectly by using radio waves to sense sudden disturbances in ionosphere (SID's)

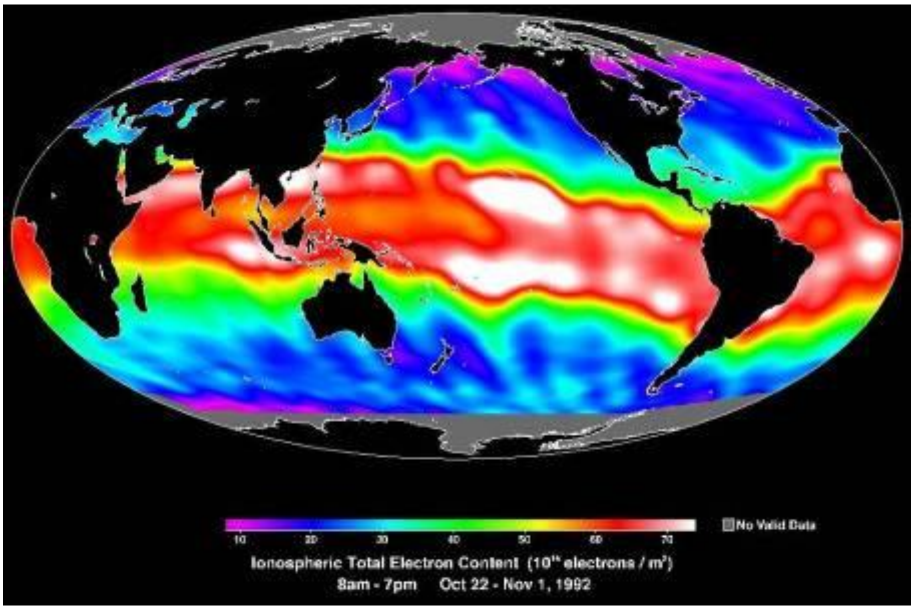

Fig 2.1. Different degrees of ionization in the ionosphere above the Earth shows the dependence on incoming solar radiation.
Credit NASA

The ionosphere is an ionized layer in the atmosphere roughly 50-600 km above the Earth's surface. Its ionization is caused by incoming UV and X-ray radiation from the sun. The degree of ionization increases with the amount of solar radiation received, and therefore tends to depend on the latitude, the season, and the time of day. Ionization is also dramatically affected by exceptional events such as solar flares and coronal mass ejections.

The ionosphere is excellent propagator of radio waves. Short wave communications such the BBC World Service are broadcast across the globe thanks to the ability of the ionosphere to carry radio waves beyond the transmitter's line of sight. The strength of the propagation by the ionosphere depends on the degree of ionization in quite complex ways that we will examine more carefully in chapter 10, but the essential point is that short terms changes in the degree of ionization can be detected by monitoring the changing power of a distant radio signal that is being carried through the ionosphere, thus indicating the occurrence of solar storms.

The kind of radio signal that we would like to monitor is ideally available all over the world, receivable at long range, and transmitted at constant power. Fortunately such a system exists. It is the Very Low Frequency (VLF) submarine communications network. The VLF band at 3-30 kHz is used for submarine communications because only such low frequencies can penetrate through sea water to be picked up by submerged submarines. There are several dozen naval transmitters in use

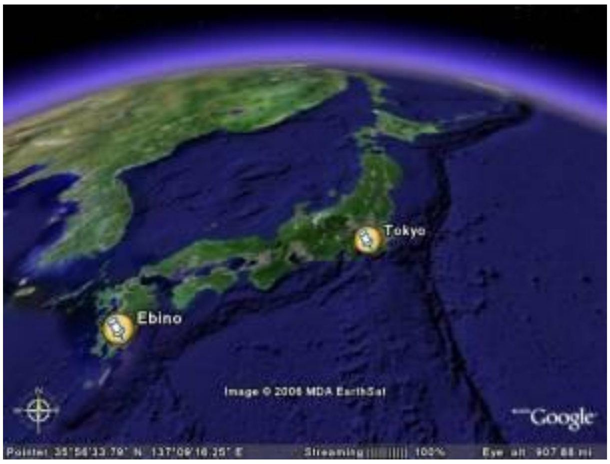

Fig 2.2. VLF transmissions from Ebino, Kuyshu, Japan propagated by the ionosphere can be received 900 km away in Tokyo. Credit: Google Earth

around the world. One of the most powerful is the 24 kHz transmitter at Cultler, Maine, USA. Another powerful transmitter is the 22.2 khz transmitter at Ebino, Kuyshu, Japan that I monitor. There are several more in Europe and chapter 4 has an up-to-date list.

Just to reassure you, it is perfectly legal to tune into these signals – the transmissions are coded and our simple equipment just measures the strength of the signal and cannot eavesdrop on secret communications. Nobody official or in uniform is going to call on you when you start operating your radio telescope.

The SSRT produces a diurnal trace that can be interpreted to reveal events such as solar storms

Let's take a quick tour of some typical traces produced by the SSRT and see how they alert us to solar storms. Figure 2.3 shows a typical signal received from my SSRT on a quiet day. The local time at the site of the radio telescope in Tokyo, Japan is on the x-axis. The power of the received signal from the VLF transmitter at Ebino, 900 km away to the south-west is shown on the y-axis. The scale is in decibels, which is simply a

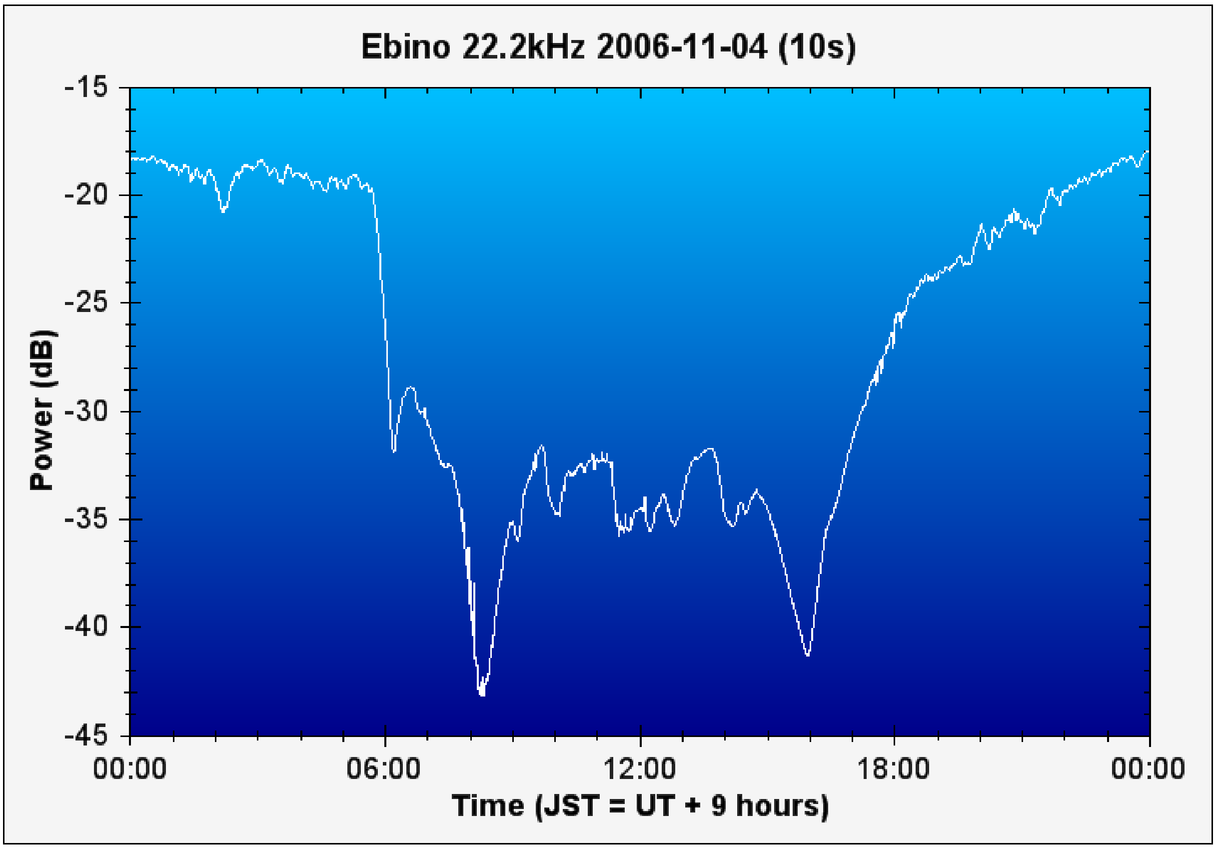

Fig 2.3. Output from my SSRT on a quiet day. The main feature is the diurnal pattern caused by the daily cycle of solar UV irradiation on the ionosphere.

The SSRT can be built simply, using a minimum of electronic components, and utilizing your home PC

Now that we've briefly understood what the SSRT is trying to do, let's take a look at what it looks like and how it works. Figure 2.8 is a block diagram that shows the whole system.

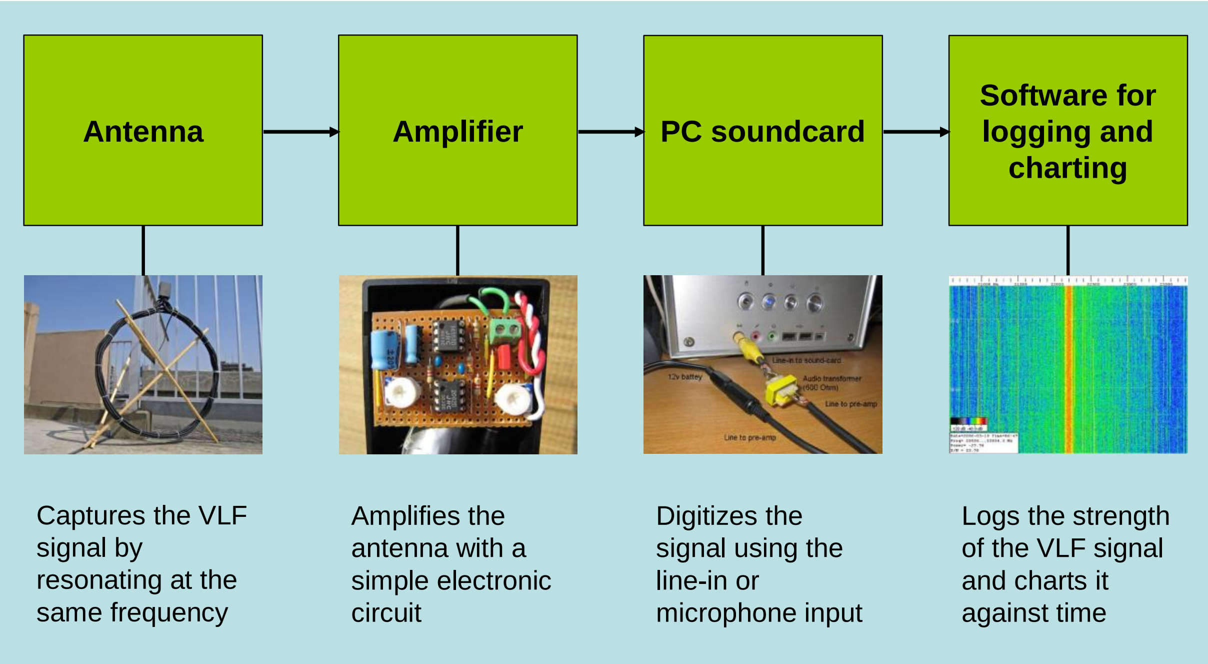

Fig 2.8. Block diagram of the SSRT. It shows the key components of the antenna, the amplifier, the PC soundcard, and the software for logging and charting

The overall scheme starts with an antenna that captures the VLF (Very Low Frequency) signal. The antenna shown in the figure is outdoors, but an indoor antenna can equally well be used – Chapter 6 has details. The received signal at the antenna is very weak. It is immediately amplified with a simple electronic circuit based on a common and inexpensive integrated circuit. The amplifier is powered by a 12V wall-wart transformer or a large battery. The SSRT is a digital system, and the amplified signal is brought along a connection cable and digitized by a PC soundcard. Custom software logs the digitized signal and graphs it against time to produce charts like the ones shown above.