

## **Learning Unit 5**

### **The Sun and Sunspots**

#### ***Objectives:***

To understand how the sun's condition varies, and how this affects radio propagation. To understand how the presence of sunspots affects the condition of the ionosphere and hence the prevailing radio conditions.

#### ***Student Preparation Required:***

Completion of previous learning units

#### ***Information:***

The sun is the source of radiation that creates the ionosphere. Any changes in the state of the sun have a major impact on the ionosphere and radio propagation conditions.

The main changes on the sun that affect propagation are related to the sunspots that appear on its surface. We find that when the number of sunspots is high, more radiation is emitted and there is an improvement in conditions on some bands. Solar flares and eruptions have the opposite effect, often causing conditions to deteriorate, or even to blackout completely at HF frequencies. However at VHF these disturbances can give rise to other forms of propagation, as we will study in future learning units.

In this unit we will look at sunspots and how they affect ionospheric radio propagation.

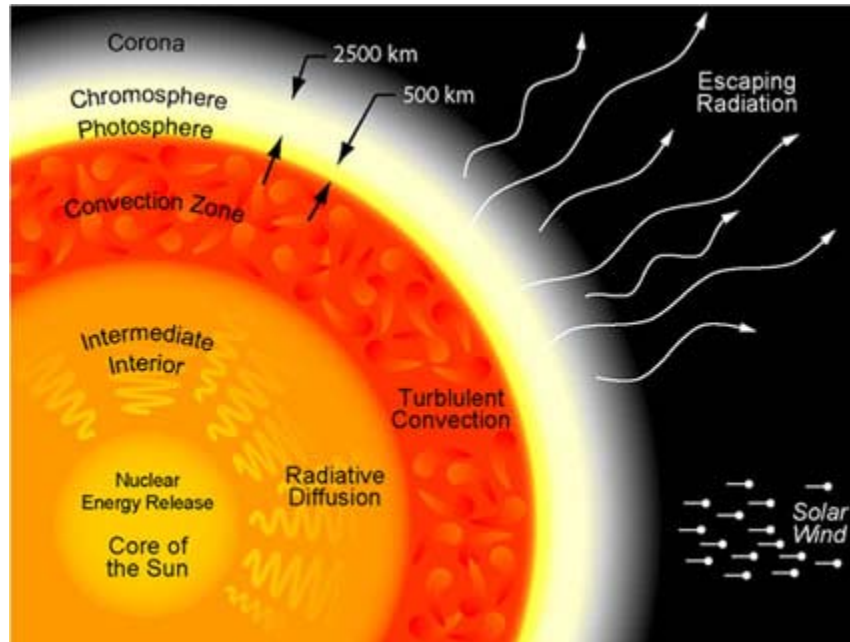
#### ***The sun***

A brief overview of the make-up of the sun and the way it radiates energy is fascinating, and very useful for an understanding of the way it affects the ionosphere and how it varies.

Its size is colossal. Its mass is about 330,000 times that of the earth, and we are about 93 million miles away from it. The sun is a gaseous body that rotates from left to right when viewed from the earth with a rotation period of 27 days. It consists of approximately 92.1% hydrogen, 7.8% helium, 0.06% oxygen, 0.03% carbon and many trace elements. Although most of the other elements that appear on earth have been detected in the sun they make up less than 0.01%.

The central core is where the sun's energy is generated. Here the density is 150 times that of water and the enormous pressures cause the nuclei of the individual hydrogen atoms to interact, undergoing nuclear fusion. The temperature in the core is around 10 million degrees Kelvin. The energy travels away from the center mainly by radiation, but the last third of the way by turbulent convection. The photosphere is the upper surface of the convection zone. The turbulent cells in the photosphere give the sun a mottled irregular appearance. The pattern is known as solar granulation, and each granule is around 1,000 miles in diameter. These granules only remain for about ten minutes. It is also possible to

see a much larger turbulence pattern. The cells in this super-granulation pattern last for a day or more and may be 20,000 miles across.

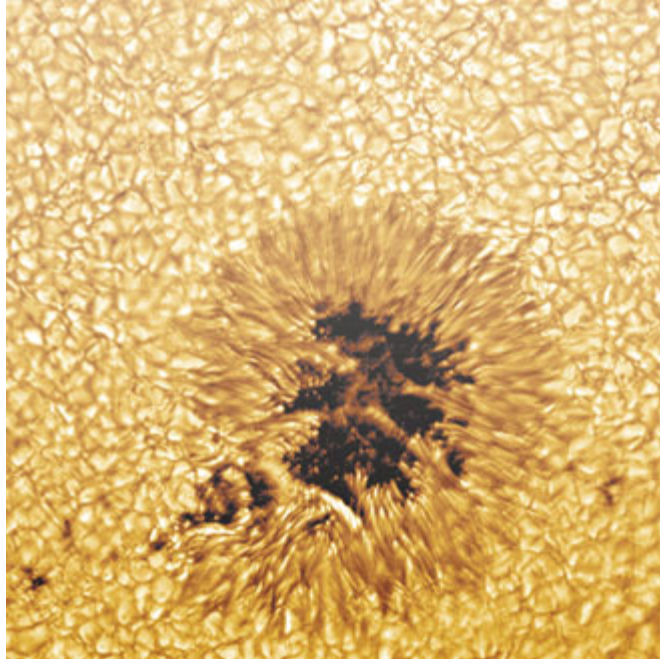


**A Model of the internal make-up of the Sun**

**WARNING: Under no circumstances should the sun be viewed directly, even through dark glasses. People have had their sight permanently damaged or even lost through doing this.**

### *Sunspots*

One of the more notable phenomena on the surface of the sun is sunspots. They appear on the surface of the sun as dark areas. They can be seen if an image of the sun is projected onto a white screen or sheet of paper. These spots may last a few days or they may be present for several months. They appear to be dark, because they have a lower temperature than the surrounding surface, typically around  $3,000^{\circ}\text{K}$  rather than  $6,000^{\circ}\text{K}$  for the rest of the surface.



**An ultra-close view of a sunspot taken by the NSO Sacramento Peak Vacuum Tower Telescope**

We believe that sunspots are caused by very intense magnetic fields that exist below the surface of the sun. The fields change over a period of time giving rise to a cyclic change in the level of sunspot activity. During a time of minimum activity the magnetic fields run from the sun's north to its south. As the sun rotates the fields rotate at different speeds, with the equatorial regions spinning more slowly than the poles. This causes the fields within the sun to change and eventually align themselves in an east west direction. At this time there is a peak in sunspot activity. The rotation of the sun continues and the fields gradually revert back to a north south direction. In this way there is a cyclic change in the level of sunspot activity.

At times these changes in magnetic field cause eruptions from the surface of the sun. Around the eruptions, the temperature of the sun's surface falls, creating dark spots.

There is a large temperature gradient around the dark spot, and there is a considerable disturbance in the magnetic field. Because magnetic fields are very strong, considerable forces are exerted. One of the results of this disturbance is that large levels of electromagnetic energy (including ultra-violet light and X-rays) are released. This energy reaches the earth and causes the gases in the ionosphere to ionize.

The size of sunspots can vary enormously. They may be anywhere between a few hundred miles to as much as a quarter of a million miles in diameter. They also often appear in clusters.

Around the dark area there is a much brighter area known as a plage (from the French word for "beach"). These are associated with the sunspots and last longer than the dark area of the sunspot. They appear before the sunspot and remain after it has disappeared.

They are important because they emit large amounts of extreme ultra-violet light which is responsible for much of the ionization in the F region of the ionosphere.

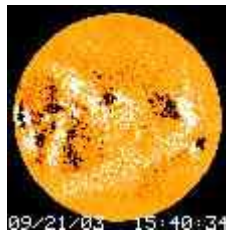
### ***Sunspot numbers***

A simple count of the sunspots that are visible on the surface of the sun at any given time does not give a good assessment of sunspot activity. Some observatories may miss spots that others would be able to count. Additionally, some spots are vastly greater than others. To help overcome this problem a scientist named Rudolf Wolf, who was director of the Zurich Observatory shortly after the discovery of sunspots, devised a system to assign a figure for the relative sunspot activity. This figure, known as the sunspot number, is not actually the number of sunspots that can be seen, but a relative figure that provides an indication of the activity.

$$R = k(10g + s)$$

- Where:
- R = the Wolf number for sunspot activity
  - k = a correction factor to take account of the equipment and observer characteristics
  - g = the number of sunspot groups
  - s = the number of observable spots (whether individually or in groups)

The formula gives higher numbers when clusters are present. Wolf arranged the formula this way because he felt that large clusters were a sign of high levels of activity and short lived single spots were not. Despite the fact that it may not be completely accurate it is still a very useful indicator of solar activity and sunspot numbers have been measured this way for over 200 years. It is very useful when looking at trends and making comparisons with previous years.



**A typical view of the sun with sunspots**

Day-to-day sunspot numbers vary widely and it is very difficult to see trends. To overcome this, the data is averaged or "smoothed" over a long period of time. There are two stages to this process. First, the daily numbers are averaged over the period of a month. Next, these figures are smoothed over a twelve-month period. To make the mean fall in the middle of the month rather than at the beginning or end, the smoothing is done over 13 months, but taking only half the value for the months at the beginning and end of the period.

$$R_s = \frac{1/2 R_{m1} + R_{m2} + R_{m3} + \dots + R_{m11} + R_{m12} + 1/2 R_{m13}}{12}$$

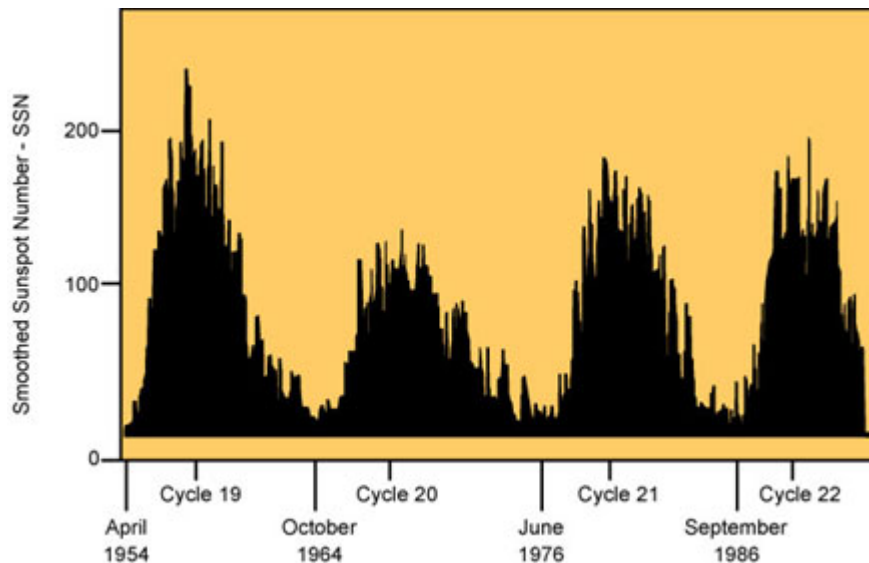
Where:  $R_s$  = the smoother sunspot number  
 $R_{m1}$  to  $R_{m13}$  = the monthly averaged numbers for months 1 to 13

Both the monthly average sunspot numbers and the smoothed values are available for use in propagation analyses. However, by their very nature the smoothed values can only be made available at least 6 months after the month being analyzed. These days the numbers are prepared by the Sunspot Index Data Center in Brussels from information supplied by a number of observatories around the world. After many years of taking daily solar data (sunspot numbers) and daily ionosphere data (critical frequencies, layer heights, etc), scientists determined that the best correlation between the Sun activity and ionospheric conditions is the correlation between the monthly median ionospheric parameters for a given month and the smoothed sunspot number for that month. Since the smoothed sunspot number for a given month requires data six months prior to and six months after the desired month, the official smoothed sunspot number is six months behind the current month. Thus, propagation predictions for the current month necessarily involve estimating the smoothed sunspot number for the desired month.

***Sunspot numbers***

Today, it is common knowledge that there is a sunspot cycle. Even though sunspot numbers have been logged since 1749, it took about a hundred years before it was clear that there is a cyclic variation in their numbers. The reason was simply that large day-to-day variations totally masked the underlying longer-term cycle. Once the figures were smoothed, cyclic variations became obvious.

The sunspot number varies over a period of approximately eleven years. These cycles are given numbers starting with cycle one in 1755. Cycle 22 finished in 1996.



**Average monthly sunspot numbers for Solar Cycles 19 to 22**

The cycles are far from constant in duration, and in the levels of peaks and troughs. The average length for a cycle is approximately 10.9 years, but it can range from seven to seventeen years. The maximum smoothed sunspot activity numbers vary from 49 to 200, but the minimum has usually been between zero and 12.

After a sunspot minimum, sunspot numbers start to rise rapidly and reach their peak in about four years. Once at peak the numbers fall more slowly, taking around seven years to drop to minimum. Like all other aspects of the sunspot cycle, these figures should only be taken as a very rough guide since they vary widely from cycle to cycle.

We will take a more in depth look at how the state of the sun affects radio conditions later in the course, but it is worth remembering that radio conditions vary broadly in line with the sunspot numbers. At the trough or minimum of the sunspot cycle the bands above 20 MHz may not support ionospheric propagation, whereas at the peak of the cycle, frequencies as high as 50 MHz and more may be affected.

Now, please click on the ***Review*** button for a brief summary of what you learned in this unit.