

## Space Weather and Radio Communications – Part One

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In the darkness of space between the sun and earth, electromagnetic radiation from radio waves to gamma-rays as well as high energy charged particles stream constantly toward the earth. Meanwhile, in the rarefied upper atmosphere of the earth far above the highest clouds, magnetic storms rage and howling winds drive atmospheric currents around the globe. Conditions in the Earth's upper atmosphere and further out into space, driven by powerful emissions from the sun, are referred to as "space-weather".

Underlying space-weather is the sun, the output of which varies over an 11 year cycle. Conditions in the upper atmosphere vary greatly at different points on the globe with the change in the zenith angle of the sun, just as with the "regular" weather on the surface of the earth. Conditions also vary throughout the day and night and with the seasons. For the radio frequency communicator, managing the effects of space-weather is essential to achieving reliable communications 24 hours a day.

The HF band is particularly sensitive to space-weather. HF, which is suited to radio communications over very long distances, is important for defence forces, emergency services, remote broadcasters and aviation and marine operators. Communications from VLF to Satellite are also affected by space-weather making its prediction and the understanding of its effects invaluable.

### Solar Activity and the Ionosphere

HF radio, which can be effective over extremely long distances, utilises a portion of the upper atmosphere known as the ionosphere. The ionosphere, which reflects HF radio waves, is created by solar radiation and is a part of the space-weather environment. The ionosphere extends from around 50 km to 500 km in altitude and is characterised by the presence of *free electrons* which can refract (bend) and sometimes reflect radio waves back to earth. The greater the density of free electrons, the greater the frequency of radio waves that can be reflected.

The free electrons in the ionosphere result from ionisation of atoms and molecules by solar radiation. Variations in chemical composition and atmospheric dynamics lead to the formation of a number of distinct bands or layers. These regions of particularly high electron density are labelled in order of increasing height as the D, E, F1 and F2 regions.

The F2 region (sometimes just called the F region), stretching from 200 km to 500 km in altitude is the most important part of the ionosphere for radio communicators. It is highest in altitude and thus provides the greatest communication range. It also reflects the highest frequencies, which is vital since absorption (attenuation) of HF decreases with increasing frequency. It is also the only layer that is ionised sufficiently to reflect HF both day and night. The lowest part of the ionosphere, the D region, is also very important as it *attenuates* rather than reflects radio waves.

With the coming of night and the absence of solar ionising radiation, the electron density in the D, E and F1 regions becomes very low. The electron density of the F2 region is also reduced at night but persists in a weakened state due to winds in the upper atmosphere which carry electrons from day-side to night-side. Thus, reflections from the night-side ionosphere occur only from the F2 region (called the F region at night).

Both the D and F regions of the ionosphere are highly sensitive to variations in space-weather and solar activity. The interaction of HF radio waves with the D and F regions varies greatly with the seasons, throughout the day and night and throughout the solar cycle.

**Figure One:** HF waves are reflected by the ionosphere at a height of between 100 km and 500 km, the reflection height depending on the frequency and electron density.

### **The Solar Cycle and Sunspots**

Space-weather is driven by the sun and follows the “solar cycle” closely. This cycle is typically about 11 years in duration and is manifest in many of the radiative and magnetic properties of the sun. The solar cycle is defined in terms of “sunspots” on the solar disk. Sunspots are regions of extremely intense localised magnetic fields which appear darker than the surrounding surface. A sunspot region on the solar surface is akin to an extreme low pressure system or cyclone on earth with intense magnetic fields rather than extreme winds.

At times, sunspots are rare and the solar disk appears almost without blemish. This occurs at *solar minimum*. Later, sunspots become common and it is normal to see numerous large sunspots, often assembled in complex groups, spread across the solar disk. The peak of the solar cycle, when sunspots are most numerous, is known as *solar maximum*.

There is a standardised way of counting sunspots present on the solar disk, to give the *sunspot number* or SSN, which is the traditional indicator of solar activity and the progress of the solar cycle. At present we are very close to solar minimum, which marks the end of one cycle and the beginning another. Over the next few years the sunspot number will rise steadily to a peak somewhere around 2012.

The difference in solar activity between solar minimum and solar maximum is quite pronounced. At the time of this article, midway through 2007, the sunspot number is around 10. At the peak of the last solar cycle in 2000, the sunspot number was around 170.

## **Sunspots and the Ionosphere**

The presence of sunspots is of particular importance to the HF communicator. Overlying and surrounding sunspots are particularly hot, bright areas called *plage* (after the French for “beach” and for the colour of sand). Plage regions produce extreme ultra-violet radiation (EUV) in especially large quantities and it is EUV which causes ionisation of the all important F region.

At solar minimum, when there are no plage regions, there is less EUV and less ionisation of the F region. Consequently, the frequencies reflected by the F region are lower. At the peak of the solar cycle, solar maximum, ionisation is greatest and the frequencies reflected by the ionosphere are highest. Higher frequencies mean reduced attenuation by the D region and increased range.

## **Solar Flares and HF Fadeouts**

Sunspots are also the site of *solar flares* which are huge explosive discharges on the surface of the sun. Massive amounts of energy in the form of radiation and matter are bound by the intense magnetic fields of a sunspot region. During a flare, the magnetic field structure collapses, releasing the energy and matter into space.

X-rays released by flares bombard the earth causing sudden and intense ionisation of the D region. This leads to increased D region attenuation of HF waves and in some cases total absorption of all HF frequencies for several hours. An “HF fadeout” only affects HF circuits that have ionospheric reflection points in the sunlit hemisphere of the earth. Night-side ionospheric reflection points are unaffected, being in the earth’s shadow and shielded from solar radiation.

Solar flares large enough to cause a total HF blackout, occur on about 300 days per 11 year cycle and are most common around solar maximum.

## **Further Ionospheric Disturbances and HF Communications**

Often associated with large solar flares is the release of huge quantities of solar matter, referred to as a Coronal Mass Ejection (CME). A CME moves away from the sun at around 1000 km/sec, expanding as it does, so that it impacts the earth within a couple of days. The earth’s magnetic field is buffeted violently by the CME, initially as a shock and then as a period of large fluctuations to the geomagnetic field.

Coronal holes are another solar phenomena that also leads to geomagnetic disturbances on earth. A coronal hole is like a window in the magnetic field structure of the sun’s corona that allows solar particles to flow more freely outward from the sun towards the earth.

CMEs are most likely to occur at solar maximum. Coronal holes are most common during the declining part of the solar cycle, from maximum to minimum, when the sun's magnetic field is decreasing in strength.

Of concern to the HF radio communicator is that a significant geomagnetic disturbance or *geomagnetic storm* in the upper atmosphere initiates an *ionospheric storm*. When this occurs, usable HF frequencies are greatly reduced and irregularities in the ionosphere result in signals travelling by multiple paths (leading to signal fading).

Major geomagnetic and ionospheric storms can last for several days, causing severe disruption to HF communications. Associated with such storm periods is also the Aurora, one of the better known ionospheric phenomena.



**Figure Two:** Aurora observed 25 August, 2005 in Southern Tasmania, Australia. Picture sent to IPS Radio and Space Services by Dallas & Beth Stott, Blackmans Bay, Tasmania.

This concludes Part One. In Part Two we look at the forecasting of ionospheric conditions and the HF frequency management support services provided by space-weather agencies such as the Australian Government IPS Radio and Space Services.

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