Newcomers Notebook.

How does a spotty sun impact radio communications?

Simple explanation without complex mathematics

by Jules Perrin VK3JFP

I have been hearing a lot about sunspots lately and realised I did not really understand what a sunspot was and the impact they have. So, I started reading and came across a humourous definition of a sunspot, I thought describes it well.

“A sunspot is a fancy name for a sun fart.”

You will read later why this humourous description is so apt.

Sun

The Sun has a diameter of approximately 1,392,083 km and is composed primarily of hydrogen. Earth in comparison is a hundred times smaller with a diameter of 12,756km.

The Sun's high temperature and pressure cause hot plasma, heated to incandescence by nuclear fusion reactions, to radiate energy mainly as visible light, infrared radiation and ultraviolet energies.

Sunspots, solar flares, and Coronal Mass Ejections (CMEs) occur during active periods of the solar cycle and are influenced by the Sun's magnetic field.

Sunspots

Sunspots occur temporarily on the Sun's surface and are visible as cooler spots darker than the surrounding area. Sunspots usually appear in pairs of opposite magnetic polarity. Their number varies according to the approximately 11-year solar cycle.

A typical sunspot has a dark region called the umbra, surrounded by a lighter region known as the penumbra and has an average diameter about the same as the Earth.

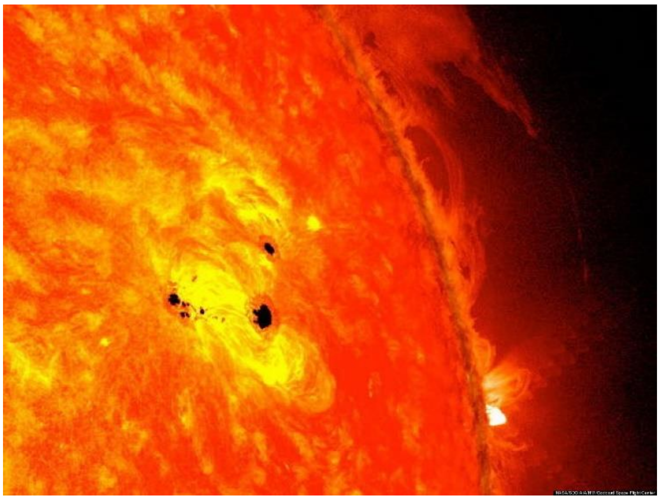

Figure 1**.** Solar activity.

Solar Flares

Solar Flares occur in regions around sunspots and are powered by the sudden release of magnetic energy stored in the outer part of the sun's atmosphere called the corona.

Solar Flares emit electromagnetic radiation across the spectrum, from radio waves to gamma rays.

Coronal Mass Ejections (CME)

CMEs are often associated with solar flares and other forms of solar activity. They release large quantities of matter into the solar wind and interplanetary space. This is primarily electrons and protons embedded within the field magnetic flux,

An Interplanetary Coronal Mass Ejection (ICME) can reach and collide with Earth's magnetosphere, where it can cause geomagnetic storms, aurorae, and in rare cases damage to electrical power grids.

The largest recorded ICME was in 1859 which disabled parts of the newly created United States telegraph network, starting fires and electrically shocking some telegraph operators.

When solar activity is at a maximum there can be about three CMEs every day, whereas near solar minimum, there is about one CME every five days.

During the periods of maximum activity, there will be an increase in the Northern (Aurora Borealis) and Southern Lights (Aurora Australis) with a possible disruption in radio transmissions and power grids.

Controllers will often relocate satellites to protect them from increased solar radiation when a strong solar flare or coronal mass ejection has occurred.

Sunspot Cycle

Sunspots oscillate over an eleven (11) year cycle. Since recording began, we are in the twenty fifth (25^{th}) cycle. From my reading, the sunspot cycles are grouped into three (3) sunspot periods.

- The Maunder Minimum was a period around 1645 to 1715 when sunspot activity was exceedingly rare. (50 sunspots). This contrasts with the typical 40,000–50,000 sunspots seen in modern times over a similar timespan.
- The Dalton Minimum was a period of low sunspot activity between 1790 to 1830. This corresponds to solar cycle 4 to solar cycle 7.
- The Modern Maximum began with solar cycle 15 in 1914 and reached a maximum in solar cycle 19 during the late 1950s. The findings are that the peak may have ended with the peak of solar cycle 23 in 2000. The low solar activity of solar cycle 24 in the 2010s marked a new period of reduced solar activity.

Ionosphere

Sunspot activity ionizing the Ionosphere (48 km to 965 km) above sea level creates a layer of electrons and the ionosphere reflects and modifies radio waves used for communication and navigation.

There are three regions (D, E and F) in the ionosphere with higher concentrations of ions and free electrons.

During the night, the ionosphere is not impacted by the sun's ionising radiation, the ionosphere is identified by two regions, the E and F layers.

During the day the ionosphere is impacted by the sun’s ionising radiation. The D layer strengthens to establish the E and D layers while the F layer separates into the F1 and F2 layers. Four layers during the day and two layers at night. These layers are shown in Figure 2.

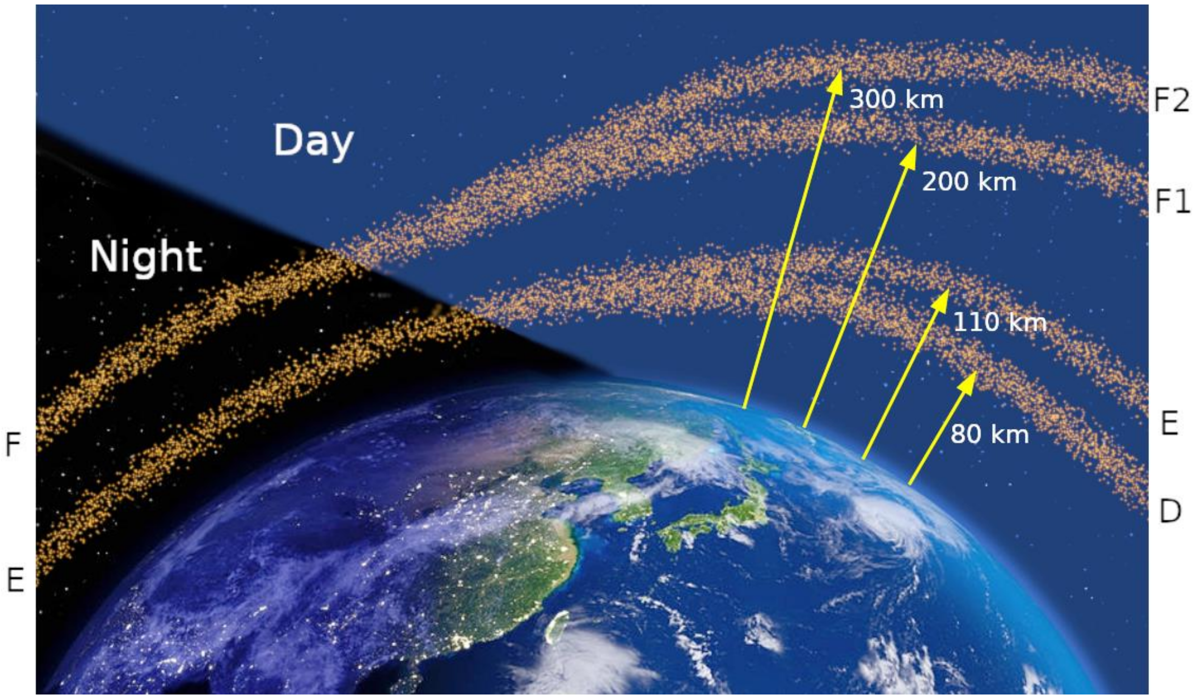

Figure 2**.** Ionospheric layers.

Ionospheric absorption / attenuation

Radio signals are reduced in strength as they pass through the ionosphere, and this can be the major contributor to the reduction in strength of signals.

The D layer accounts for the greatest absorption of radio waves. The second factor in absorption by the D layer is the frequency. The lower the frequency, the greater the absorption by the D layer.

When several bands support HF propagation between two radio stations, then the higher frequency will yield the better long-distance results. The D layer dissipates at night, no ionising radiation, so lower frequency signals are heard from much further afield.

Figure 3 demonstrates the frequency variation as the ionosphere changes from day to night.

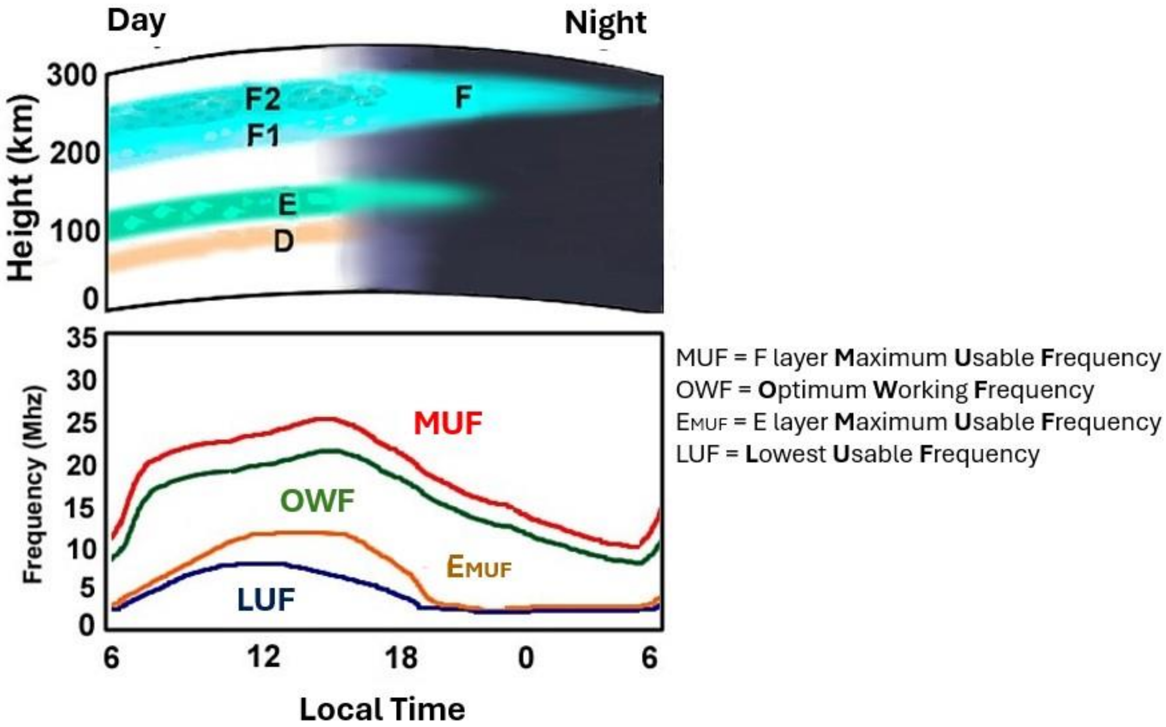

Figure 3**.** Frequency variation.

Sunspot effectiveness

There are four periods when sun sunspots impact the ionosphere and are critical for predicting propagation.

- **Time of day**: The ionosphere is more ionized during the day.
- **Location**: Regions of the Earth are ionised differently depending on their position relative to the sun.
- **Seasons:** The ionosphere's density and composition can vary with the seasons. In summer, the F1 and F2 layers are higher than in winter.
- **Solar activity**: Solar flares and geomagnetic storms alter ionospheric conditions.

Angle of incidence

The angle, with respect to Earth, that the signal leaves the antenna is important in determining long distance communications.

The ionosphere causes HF radio waves to be refracted (bent) and eventually reflected to earth. The greater the density of electrons in the ionosphere, the higher the frequencies that can be reflected.

Signals reaching the ionospheric at shallow angles, like the blue signal in Figure 4, will need little refraction to be reflected to Earth. Signals reaching the ionosphere with a more vertical incidence, like the red signal in Figure 4, will need a greater degree of refraction.

The downside is that the D region of the ionosphere will absorb signals passing through it at a shallow angle.

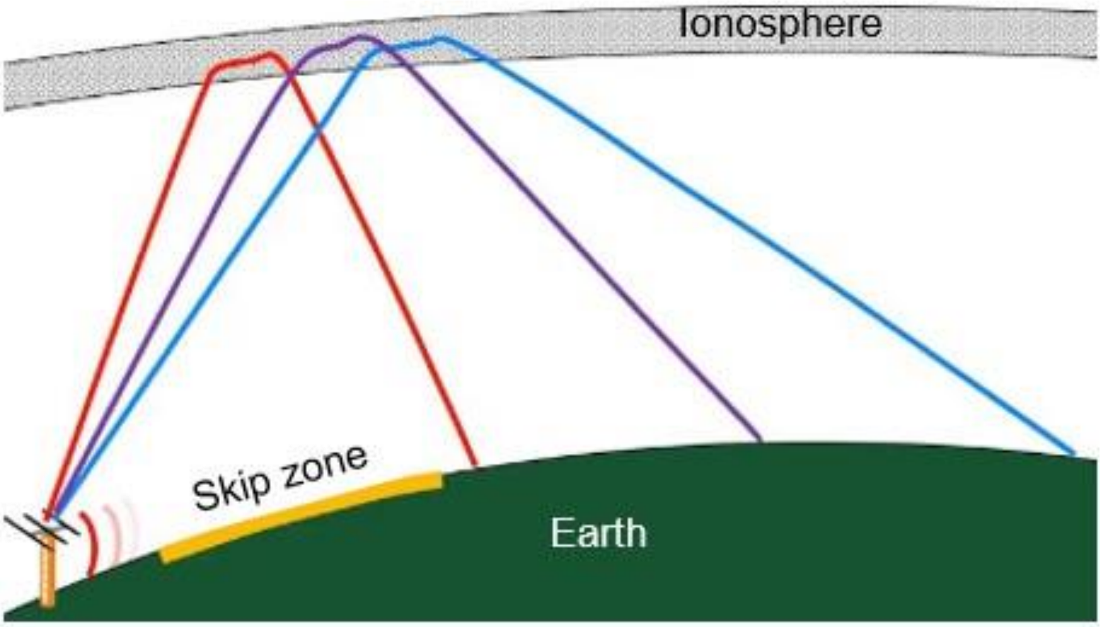

Figure 4**.** Signal angle of incidence.

Overall, the shallow angle signals are transmitted the farthest distance.

Radio propagation prediction

As we have seen, there are many aspects that impact radio wave propagation. There are two aspects that give the best clues to the potential state of radio communications propagation. These are the solar flux and the geomagnetic indices known as the A and K indices. These indices consider the position on the globe, time of day, season, and the position in the sunspot cycle.

K Index

The K index is calculated, at many separate places around the world, every three hours based on a magnetometer reading.

Kp Index

The averaged K index.

A Index

The A index is a linear measure of the Earth's field. Values for the A index range up to 100 during a storm and may rise as far as 400 in a severe geomagnetic storm.

Ap Index

The averaged A index.

Figure 5 demonstrates the relationship between the K indices and Ap indices.

Propagation Indices	
K Index	**Ap Index**
0	Inactive
1	Very Quiet
2	Quiet
3	Unsettled
4	Active
5	Minor Storm
6	Major Storm
7	Severe Storm
8	Very Severe Storm
9	Extremely Severe Storm
The best HF propagation is available when the K index is less than 5. Less than 3 is a god indication 40 and 80 metre band is quiet.	

Figure 5**.** Propagation Indices Table.

T Index

The T index is an indicator of the highest frequencies able to be refracted from regions in the ionosphere. The higher the T index, the higher the frequencies able to be reflected from an ionospheric region.

Services

There are many prediction services on the internet. These you can explore. One worthy of a little exploration is the HAP chart.

HAP Charts

Hourly Area Prediction (HAP) charts are designed for communications between stations. Your location is the base, and the HAP chart provides information on the best frequency to contact the distant station.

HAP Chart Source

The charts are provided by the Space Weather Forecasting Centre under the Bureau of Meteorology.

Goto the web site at https://www.sws.bom.gov.au/HF_Systems/7/1.

1. Select HF Prediction. A world map with night and day will be shown.
2. Move the mouse to your location and left click. A blue triangle indicating the “Base” will appear on the map.
3. Move the mouse to the area you wish to communicate with. Left click the mouse and a pink square shows this area.
4. The pink square can be expanded to suit your selection.
5. When you have selected your coverage area, select “Predict” at the top right of the map.
6. The result will be like Figure 6. The colours on the HAP chart show the recommended HF frequencies for contact. The colour at the distant operator station is the frequency you would use.

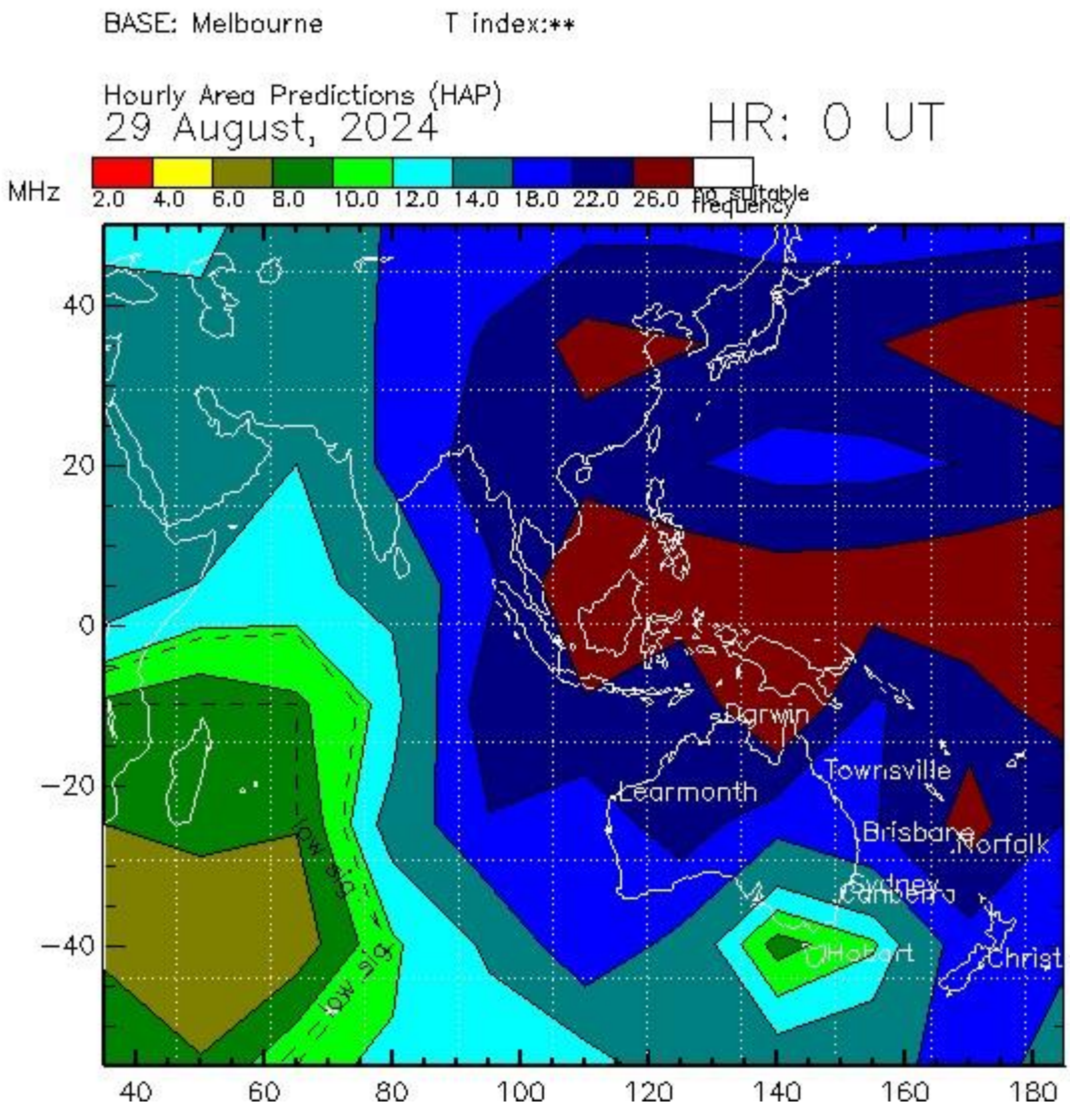

Figure 6. Sample HAP Chart.

In this case, if the operator in Melbourne wanted to contact Eastern India, the ideal frequency is 14MHz. Whereas seeking contacts in Papua New Guinea (PNG) around 26 MHz is best.

This site contains a more information than what is covered in this short article and is worth exploring now you have a basic understanding of the causes of communication disruptions.

Have fun and stay safe.