Solar Activity and its Major Impacts On
High Frequency Radio Transmissions
Mike Brown – KX4YZ
May 26, 2025

High frequency ("HF") radio communications are impacted to a significant degree by fluctuations in solar activity and associated emissions. Such phenomena as coronal mass ejections ("CMEs"), solar flares, and typical radiation in the electromagnetic spectrum from the sun are chief among these. The solar activity that drives the occurrence of CMEs and solar flares is not exactly constant. It is well known that there is a direct relationship between sunspot activity and these emissions such that the amount of radiation from the sun varies not only with the 11-year solar cycle but also with the 11-day period associated with the rotation of the Sun on its axis[1]. Below we will discuss these events, their mechanisms, and the related impacts on HF propagation.

The regular emission of radiation in the form of photons released across a broad portion of the spectrum by the sun and traveling at the speed of light goes on continuously. When these emissions are photons in the ultraviolet, extra ultraviolet, and X-ray wavelengths, there is an interesting effect on the F layers of earth's upper atmosphere. Radiation from the sun, primarily in the form of these incoming, energetic photons, dislodges electrons from molecules and atoms in the ionosphere separating them into positively charged ions and free, negatively charged electrons ("**ionization**"). It is accumulations of these free electrons in the F layers that act to bend radio signals back to the surface of the earth and thus, to a major degree, are responsible for producing the "skip" of transmissions familiar to HF ham radio operators. Naturally, this phenomenon is most active during the day. At night, the ions and free electrons to some extent recombine. Through this recombination process, the number of free electrons is reduced. Since it is only *a portion* of these particles that recombine each night, several days in succession of abundant ionization builds the number of free electrons. Time of day, season, pre-existing accumulation of free electrons, and sunspot activity are all factors that can affect the extent of ionization present in our atmosphere at any point in time.

---

[1] 4.1.2 WHAT IS THE NATURE OF LIGHT RADIATED BY THE SUN? National Aeronautics and Space Administration Goddard Space Flight Center Lecture https://acd-ext.gsfc.nasa.gov/anonftp/acd/daac_ozone/Lecture4/Text/Lecture_4/sunrad.html accessed 05/11/2025

Solar Flux is a measurement of radio noise at the 10.7 cm wavelength (2800 MHz) and is an indication of the **level of ionization existing in the upper atmosphere**[2]. Solar Flux is stated in terms of "Solar Flux Units" or "SFU". Current Solar Flux data is widely available from several internet sources.

So as we can see, this ionization in the upper ionosphere due to radiation from the sun is a good thing for HF ham radio operators, but there is another solar activity that degrades HF radio propagation; solar flares, CMEs, and other solar activity which produce bursts of electromagnetic radiation often increase the level of **geomagnetic disturbances** in the earth's magnetic field (the magnetosphere), creating geomagnetic storms. These storms are particularly disruptive to HF transmissions. A common measurement of geomagnetic disturbances around the earth from these and other sources are the **A and K Indices** which we will discuss below.

Solar flares themselves are rated as they take place based on the intensity of their apparent X-ray brightness on a scale from B-Class (weakest), followed by C-Class, then M-Class, and finally the strongest, the X-Class flares. Each of these designations is 10 times stronger than the preceding designation. For example, an M-Class storm is 10 times stronger than a C-Class storm and 100 Times stronger than a B-Class storm. Subdivisions within the B through M ratings from 1 to 9 provide for finer interpretation. X-Class storms are not limited to a subdivision rating of 9 and can be higher. For example, one especially powerful storm in 2003 overloaded the sensors measuring it. The flare was eventually rated as an X45[3].

Coronal Mass Ejections ("CMEs") and the solar wind are by far the predominant sources of charged particles from the sun. CMEs throw out billions of tons of coronal plasma with embedded magnetic fields. The magnetic field moving along with the conductive fluid (the plasma) is considered "frozen in flux" meaning that the field lines are tied to the plasma as the field moves along with it through interplanetary space[4]. CMEs are not rated as they occur on the same scale that applies to solar flares but are assessed based on speed, size, and magnetic field orientation using data gathered by orbital satellites. The matter produced by CMEs (primarily protons) races across space at speeds from 155 miles per second to as much as 1,900 miles per second. Accordingly, the plasma reaches Earth anywhere from less than one day to as much as three days after the event. Not all the aspects of these CMEs are well understood by scientists yet.

[2] This wavelength is a good indicator of solar activity, specifically emissions from the upper chromosphere and lower corona. While the choice of 10.7 cm was originally due to radar technology available during World War II, it has proven to be a useful wavelength for monitoring solar activity. From THE HISTORY OF THE 10.7 CM SOLAR FLUX Space Weather Canada https://www.spaceweather.gc.ca/forecast-prevision/solar-solaire/solarflux/sx-2-en.php accessed 05/09/2025.

[3] X-CLASS: A GUIDE TO SOLAR FLARES NASA https://svs.gsfc.nasa.gov/10109 accessed 05/13/2025

[4] CORONAL MASS EJECTIONS Space Weather Prediction Center National Oceanic and Atmospheric Administration https://www.swpc.noaa.gov/phenomena/coronal-mass-ejections accessed 05/11/2025

A detailed discussion of the mechanisms of disturbance of the earth's magnetic field by this matter is beyond the scope of this paper, but it does create dynamic atmospheric conditions that can and do affect radio waves, the electric grid, satellites, and other infrastructure. We do also know that it is these charged particles from the sun that are responsible for the beautiful auroral displays seen in the northern and southern skies.

As previously noted, both the K and the A Indices measure geomagnetic conditions around the earth. The K Index is a local, quasi-logarithmic index measuring the 3-hour range of the magnetic state at a specific place. The A Index is derived using data from the K Index that is scaled to a linear value and averaged over a full day. Thus the K Index is more localized and detailed, but the A Index is a more global average value and is easier to use in other calculations. The A Index ranges from 0 to 400 but values around 100 are common. A value of 200 (which is considered severe) is not rare.

The K Index is on a scale of 0 to 9. K Index Values of 0 to 1 indicate mild magnetic conditions where HF radio works well. K Index values of 2 to 4 represent a disturbed state or active geomagnetic conditions where some difficulties begin to occur with HF signals. If the K Index value is 5, a minor geomagnetic storm is occurring. K Index values of 6 and up through 9 are very high and can severely negatively affect or even blackout HF radio transmission[5].

Related versions of these indices are also calculated and available such as the K_p and A_p Indices. These are the *planetary* values providing a global assessment.

Even though the F layers are considered the major players in ionospheric effects on ham radio communications, the other layers have their implications for the hobby. **The E layer** of our atmosphere is between 56 and 93 miles above the surface. As with other layers, the E layer varies in its effect on radio waves as solar activity fluctuates. For some lower frequencies, the powerful **absorption by the underlying D layer** during the daytime makes the effects of the higher E layer indistinct. Ham operators attempting to use 40-, 80-, or 160-meter bands during daylight hours will typically not be able to pass signals through the D layer with workable strength. Perhaps the E layer is best known among ham operators for the occurrence of **Sporadic E ("Es")** conditions which take place at seemingly random times often temporarily improving the propagation in various portions of the radio spectrum, **principally in the VHF and UHF bands**. This happens when **extremely dense** "clouds" of ionization develop in the E layer, commonly during the late spring and early summer. Just as the occurrence of these conditions is unpredictable, the impact of them on radio waves is likewise inconsistent; sometimes improving conditions and at other times deteriorating radio signal propagation.

5 High-Frequency Communications Response to Solar Activity in September 2017 as Observed by Amateur Radio Networks American Geophysical Union https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018SW002008 accessed 05/14/2025

Notably, there are related outstanding events of Sporadic E such as Equatorial Es, Auroral Es, and others for which additional reading is suggested. An excellent series of articles by Professor David Whitehead for QST magazine will provide a good understanding of some of the physics if you are curious about a deeper dive.[6]

Solar impact on the **D layer** of the atmosphere contrasts with that occurring in higher layers. The D layer, 37-56 miles above the earth's surface, is **much denser** than the upper layers. Ham operators know that the D layer commonly **absorbs** and attenuates radio signals, specifically during daytime hours. This absorption is due to the collision of radio waves with particles in the atmosphere. Due to the **much denser concentration of molecules, ions, and free electrons in the D laye**r compared to the upper layers, collisions between the radio waves and these particles are understandably more frequent there. Accordingly, while ionization in the F1 and F2 layers improves skip, ionization in the D layer **increases the level of the absorption** of radio waves. There is a strong indirect relationship between the frequency of radio waves being transmitted and the degree of absorption in the D layer discussed below. Respecting solar activity and its relationship with D layer conditions, absorption is much more prevalent during periods of peak solar activity (daytime). Also, solar flares are known to exacerbate this absorption due to the attendant increase in ionization.

It's noted above that the level of absorption in the D layer is greatly dependent upon the **frequency** of the radio wave being transmitted. **Lower frequencies are conspicuously more degraded by the D layer's absorption and attenuation than are higher frequencies**. The 20-meter band and higher frequency bands such as 17, 15, 12, and 10 meters are not so much affected as lower frequencies. As you might expect, 80 and 160 meters are dramatically degraded by this phenomenon to the extent that they are almost unusable during the daytime. It follows that lower frequencies are most effective at night.

Ions in the D layer recombine very rapidly with neutral atoms after dark causing a quick drop-off in absorption in the layer. This again is due to the D layer's density. The "greyline" that ham operators are familiar with is known to be the best times of day for long-distance skip propagation since those are brief periods wherein a combined decline in ionization in the D layer coupled with a slower decay of beneficial electrons in the F-Layers creates favorable HF conditions. Absorption in the D-layer declines and reflective properties in the F1 and F2 layers continue for some time.[7]

---

[6] Sporadic E—A Mystery Solved? QST, David Whitehead https://www.arrl.org/files/file/Technology/tis/info/pdf/9710039.pdf accessed 05/23/2025

[7] D Layer Absorption – Big Radio Sponge Enjoying Radio and Maker Hobbies https://play.fallows.ca/wp/radio/shortwave-radio/d-layer-absorption-big-radio-sponge/ accessed 05/23/2025

Summary – For good HF conditions to exist, Solar Flux should be at 150 SFU or more for a few days, and the K Index should be 2 or below. This information is available from several sources, and prediction models taking this information into account are available on the internet. HF ham radio operators should become familiar not only with internet HF propagation prediction models but also should be directly familiar with the underlying physics of solar effects and the related interplay between the earth's atmosphere and the sun.

Lower frequency long-distance propagation is best at night. Greyline periods (during dawn and dusk hours in a boundary between day and night) provide special favorable conditions for ionospheric propagation.

Helpful Internet Links not footnoted:

- NASA Space Weather Prediction Center:
  https://www.swpc.noaa.gov/products/station-k-and-indices
- Understanding HF Skywave Propagation:
  https://www.qsl.net/4x4xm/Propagation/Live-HF-Propagation-Map.htm
- SSpaceWeatherLive.com:
  https://www.spaceweatherlive.com/
- NOAA Planetary K-Index:
  https://www.swpc.noaa.gov/products/planetary-k-index
- NASA Solar Cycle 25:
  https://science.nasa.gov/blogs/solar-cycle-25/
- SpaceWeatherLive.com:
  https://www.spaceweatherlive.com/en/solar-activity/solar-flares.html
- VOACAP ONLINE:
  https://www.voacap.com/hf/