of extremely intense activity have been observed from a single sunspot region during solar minimum. This can cause short term openings on the higher frequencies. Large numbers of very low radiation sunspots have also been observed during a solar maximum. This allows unexpected propagation conditions to exist at either solar minimum or maximum.

A useful indication of overall solar activity is the solar-flux index, a number associated with the measured radio noise coming from the sun at 2800 MHz. One such measurement is made at 1700 UTC daily in Ottawa, Canada. The latest solar-flux index is transmitted at 18 minutes past every hour by WWV. Because it is a current measurement for solar activity, it tends to be more useful in predicting propagation conditions than the more traditional sunspot number. This solar flux, more commonly called *10.7-cm solar flux* or *2800-MHz solar flux* can be directly related to sunspot number using the chart shown in Fig. 8.

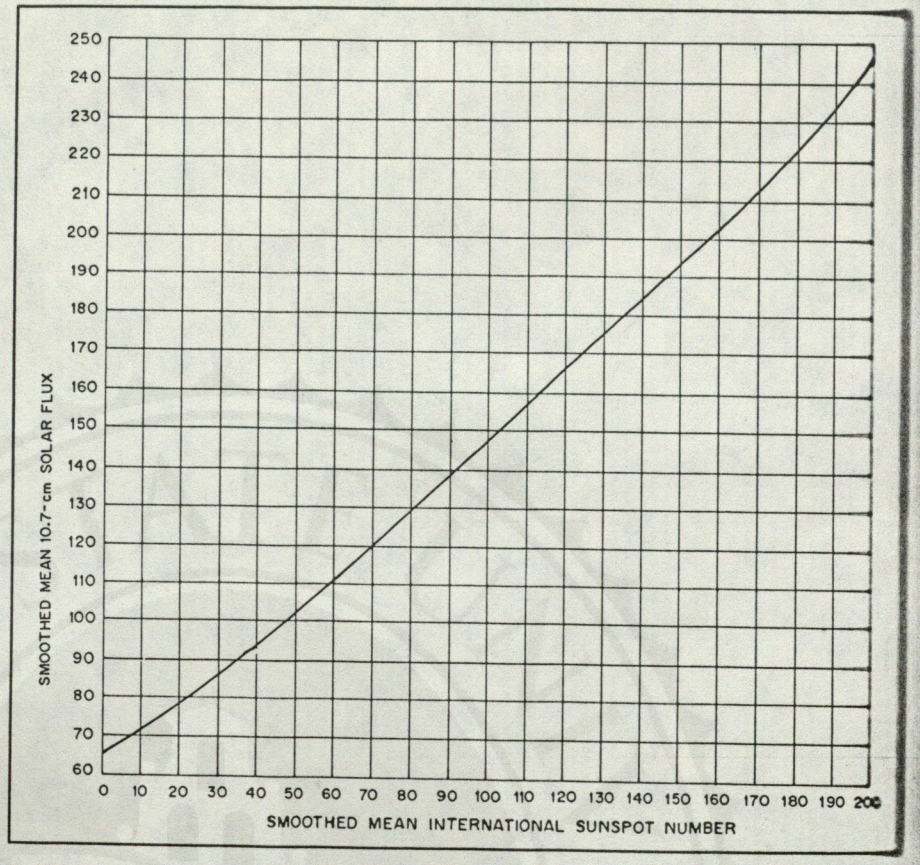

Fig. 8 — Relationship between the smoothed mean sunspot number and the 2800-MHz (10.7-cm) solar flux. In the low months of a solar cycle, flux values run between about 66 and 86. Intermediate years may see values of 85 to 150. The peak years of Cycle 21 brought readings between 140 and 380, in 1979 and 1980.

Solar Radiation

There are two types of radiation from the sun that influence propagation; electromagnetic and particle emissions. The electromagnetic emissions include X-rays, ultraviolet (UV) and extreme ultraviolet (EUV). Each has an impact on a different part of the ionosphere. Particle emissions come in two forms: high-energy particles (high-energy protons and alpha particles) and low-energy particles (low-energy protons and electrons). The different types of radiation travel from the Earth to the sun at different speeds and have varying effects on sky-wave propagation. The time it takes for each type of radiation to travel from the sun to the Earth is shown in Fig. 9. The effects that result from each radiation type are also summarized in this figure.

EUV ionizes the ionospheric F region and is always present at some level. During solar maxima, the increased number of active regions on the sun provide for increased EUV, which in turn increases the F-region ionization and allows the use of higher frequencies for long-distance communication. UV and X-ray emissions ionize the D region, which absorbs HF energy. During solar flares, UV and X-ray emissions increase, causing increased signal loss on those HF circuits facing the sun. It takes about 8 minutes for electromagnetic emissions from the sun to travel to the Earth, because this energy travels at the speed of light.

High-energy particle radiation travels more slowly than light, and reaches the Earth from 15 minutes to several hours after a large solar flare. The high-energy particle emissions cause much higher absorption in the Earth's polar regions. They also create a radiation hazard to satellite systems and personnel orbiting the Earth in spacecraft. The lower-energy particles travel even more slowly, and cause magnetic disturbances, auroras, sporadic E and increased polar-region absorption. These emissions arrive 20 to 40 hours after the solar flare has occurred.

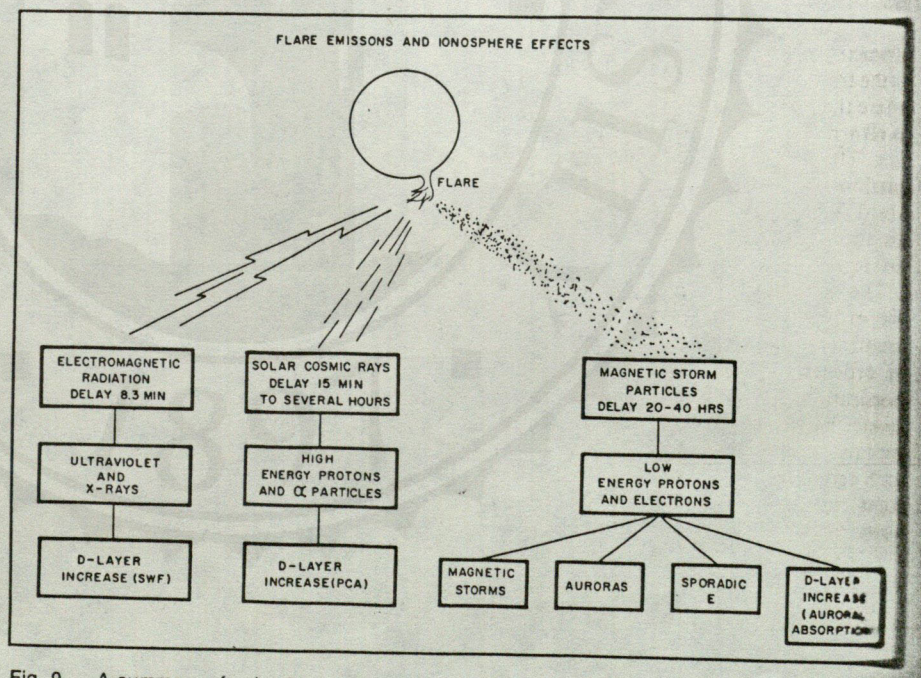

Fig. 9 — A summary of solar flare emissions and ionospheric effects.

It is difficult to compare solar activity to ionospheric variations because the chief ionizing agent for the F-region of the