Sudden Frequency Deviations and Radio Blackout Observed at Anchorage, Alaska

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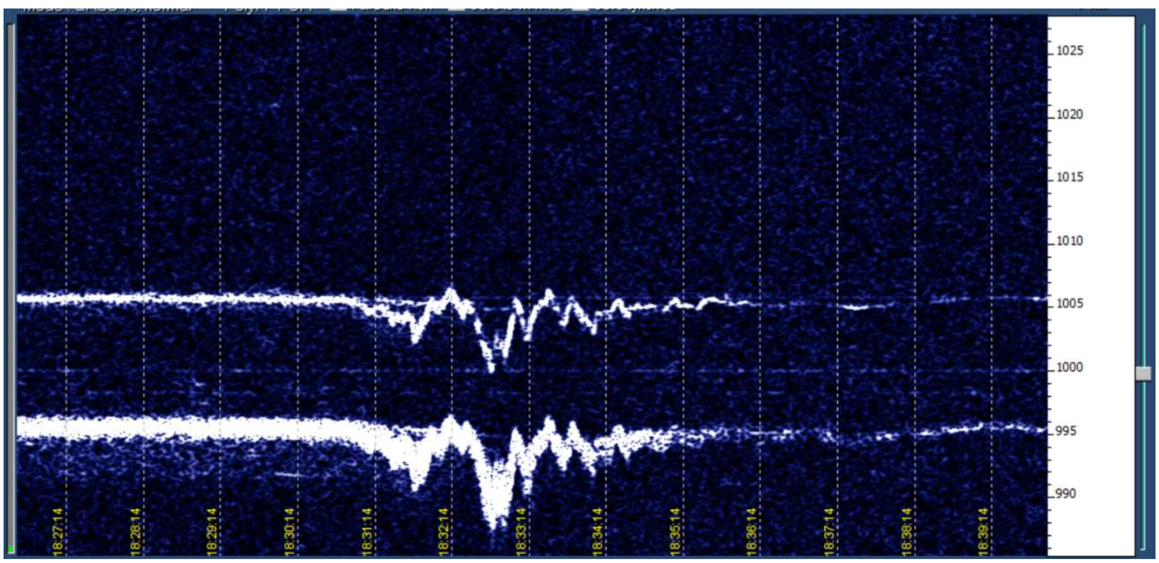
An X1.0 x-ray flare on 1 June 2024 produced interesting sudden frequency deviations (SFD), shown below, at 15 and 20 MHz as well as a broad radio blackout observed from 10 to 23 MHz, shown following. The flare began at 1824, peaked at 1836 and ended at 1849 UTC and was produced by active region 3697 on the southeastern quadrant of the Sun facing Earth. The flare also produced continuum radio emissions and radio bursts over a wide frequency range.

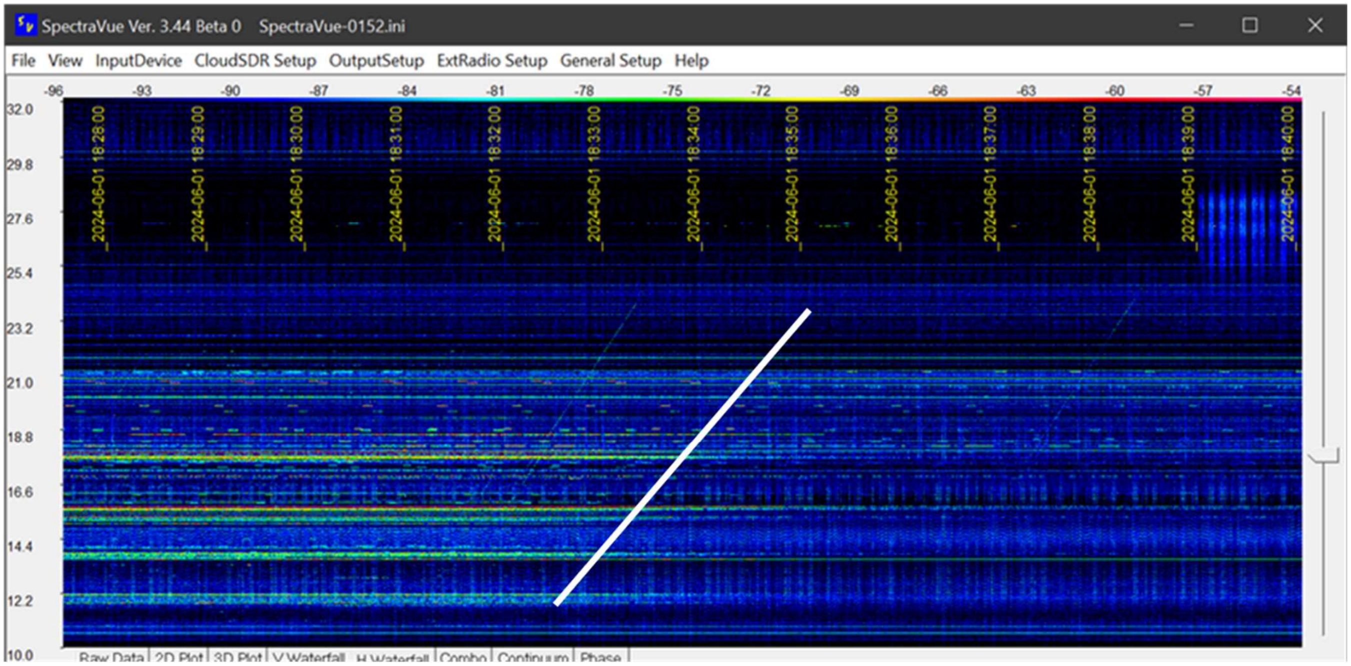
SFDs result from the reaction of the ionosphere and skywave radio propagation to flare radiation: {https://reeve.com/Documents/Articles%20Papers/Propagation%20Anomalies/Reeve_SuddenFreqDevConcepts_P1.pdf }. From that paper in italics:

Two ionospheric conditions are attributed to sudden frequency deviations, both caused by the x-ray, extreme ultraviolet and ultraviolet energy released by a solar flare. First, a slab of ionosphere below the reflection region along the radio path undergoes a rapid change in refraction index and, second, the ionosphere's reflection region undergoes a rapid vertical movement. Both conditions introduce a Doppler shift in the radio wave by changing the effective path length and, thus, the wave number. Either one or both together can cause a sudden frequency deviation.



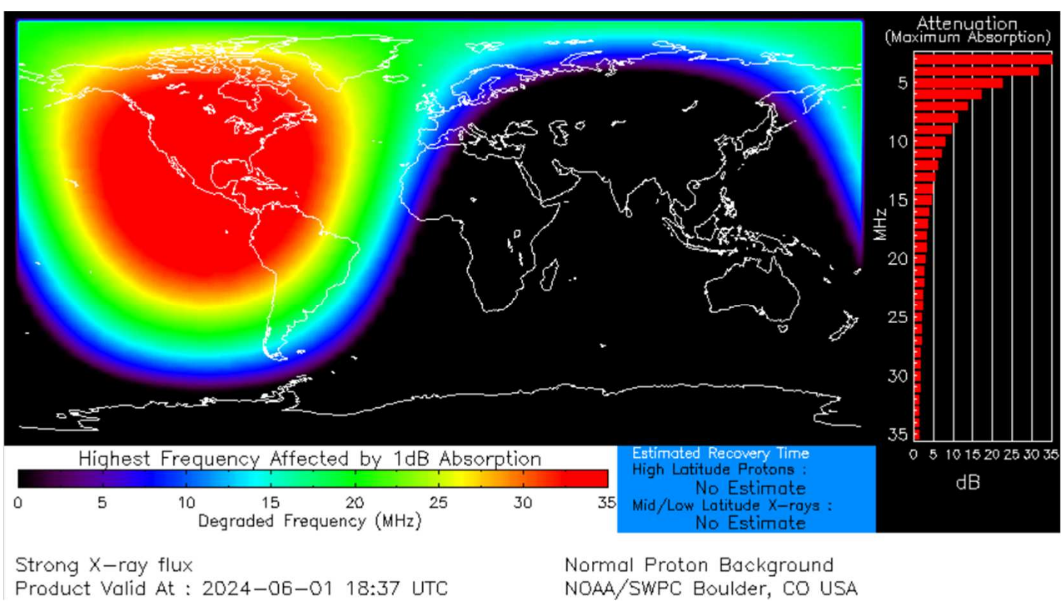
Narrowband spectra from 1827 to 1840 observed at Anchorage, Alaska. Time is measured left-to-right with 1 minute tick-marks (dotted vertical yellow lines). The frequency of the demodulated carrier is shown on the right vertical scale from 985 to 1030 Hz. The lower trace at 995 Hz corresponds to a 15 MHz carrier frequency (WWV or WWVH), and the trace at 1005 Hz near the middle of the frequency scale corresponds to a 20 MHz carrier frequency (WWV). The SFD starts at 1831 at both frequencies with maximum peak-to-peak deviation of approximately 9 Hz at 15 MHz and 5 Hz at 20 MHz. The SFDs show interesting time-correlated periodic structures lasting about 4 minutes. The fainter traces following the SFDs indicate the onset of the radio blackout and reduced received signal levels. The receivers were Icom R-8600 *Communications Receivers* and the antenna was a KMA-1832 log periodic dipole array. The narrowband horizontal waterfall plot was produced by Argo software.

In addition to the sudden frequency deviations, a radio blackout was recorded from 10 to 23 MHz and is shown in the broadband horizontal waterfall spectra below.



Broadband horizontal waterfall spectra from 10 to 32 MHz (left vertical scale) covering the time period 1828 to 1842. The slanted white line, starting at about 1833 and 11 MHz, shows the approximate demarcation between preflare and postflare spectra with the reduction in received signals seen to the right of the line. Heavy local radio frequency interference is obvious in the spectra and is unaffected by the radio blackout. The timestamps along the top of the plot are at 1 minute intervals. Received signal power is indicated by the color palette above the timestamps. The receiver is an RFSpace CloudSDR *software defined radio receiver* connected to a KMA-1832 log periodic dipole array. The software is SpectraVue.

To complement the actual blackout recording above, the estimated radio frequency absorption levels at the time of the radio blackout are seen in the D-Region Absorption Prediction (D-RAP) plot below.



The D-RAP plot at 1837 UTC shows absorption at frequencies as high as 35 MHz over a wide range of latitudes on the sunlit side of Earth. The maximum absorption exceeded 30 dB at 5 MHz (right-hand scale) from the flare radiation. Image source: https://www.swpc.noaa.gov/products/d-region-absorption-predictions-d-rap