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Unexpected VLF bursty-patches above 5 kHz: A review

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Unexpected short patches of natural VLF emissions at frequencies above about 5 kHz have been revealed at the ground-based station Kannuslehto (KAN, L ~ 5.5) in Northern Finland. In contrast with classical VLF emissions (e.g., chorus, hiss and quasi-periodic emissions) these new unusual high-frequency bursty-patches have been observed at frequencies much higher than half of the equatorial electron gyrofrequency corresponding to the L shell of KAN. Moreover, most of these waves reached frequencies above the equatorial electron gyrofrequency at L=5.5. Thus, they cannot be attributed to the standard VLF theory and require a detailed investigations of their morphological properties.

Here we present a review of the results of the analysis of these newly discovered VLF bursty-patches at KAN during winters 2011-2021. These emissions have rarely been observed in spectrograms because they are usually hidden by strong impulsive atmospherics (sferics, originating in lightning discharges) in the same frequency range. A special numeric filtering technique was applied to reduce sferics noise allowing us to better observe these new high-frequency VLF emissions. They typically occur as sequences of short right-hand polarized burst-like patches with a separation of ~1-3 min and lasting several hours.

Here we discuss the spectral structure of such VLF bursty-patches events with durations of 6+ hours, and the individual bursty-patches properties. Two different spectral categories of VLF bursty-patch emissions have been established: (1) "*triggered-like"* VLF hiss-like bursts at frequencies between ~4.0 and 6-7 kHz with a very abrupt onset and detected under quiet geomagnetic conditions, and (2) "*dash-like"* emissions at frequencies above ~6-7 kHz. In contrast with "*triggered"* emissions, high-frequency "*dash-like*" patches are observed under moderate geomagnetic activity.

Even though VLF bursty-patches in the winter seasons of 2011-2021 were observed under weak or slightly disturbed magnetic activity, the annual cyclical variations in their appearance were similar to the cyclical variations in the solar activity. The nature of these VLF patches has not yet been exactly established. It seems that they are generated inside the magnetosphere at L shells lower than that of KAN, but the exact generation region and propagation behaviour of these emissions remain unknown. Further theoretical and experimental research is required.

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