FURTHER INVESTIGATION OF AURORAL ROAR FINE STRUCTURE

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Through unknown processes the aurora emits electromagnetic waves, which are detectable on the ground particularly during substorms, at two and three times the ionospheric electron gyrofrequency (f_{ce}). LaBelle et al., [1995] captured two $2f_{ce}$ auroral wave events during automatic operation of a narrowband downconverting receiver at Circle Hot Springs, Alaska. The emissions are composed of a complicated pattern of multiple fine structures rising or falling in frequency. To better characterize the fine structure of these auroral emissions, the same downconverting receiver was operated at Churchill, Manitoba, during a three week period in April, 1996. In this experiment, the center frequency of the receiver was tuned in real–time by an operator who simultaneously monitored the wave activity with a companion stepped frequency receiver.

The time durations of observed fine structure ranges over six orders of magnitude, from the minimum measurable limit of tens of milliseconds to tens of seconds. The new data establish that the majority of auroral fine structure features are typically less than a few seconds in duration and predominantly less than 1 s. Fine structure features which drifted in a constant manner were observed as well as those drifting in a variable or wavy manner. The slopes of constant drifting features vary greatly from ~ -800 kHz s^{-1} to $\sim +100$ kHz s^{-1}. Several stationary features were analyzed to determine an upper bound of 6 Hz full width at -3 dB on the minimum bandwidth of fine structure. Some generation mechanisms may be eliminated on the basis that they provide no feasible explanation of this observed fine structure.

There are currently two competing categories of auroral roar generation mechanisms: direct and indirect. An example of a direct mechanism involves the cyclotron maser instability and requires cavity-like structures of the electron density n_e in order to reflect the waves (e.g. Yoon et al., [1996]). An example of an indirect mechanism involves the excitation of upper hybrid waves when $f_{uh} = 2{,}3 f_{ce}$ followed by their conversion to electromagnetic waves which propagate to the ground (e.g. Kaufmann, [1980]). Both classes of mechanisms can be considered in terms of a source emitting at two and three times the cyclotron frequency in a dipolar magnetic field. Using this relation the maximum frequency drift observed (-790 kHz s^{-1}) corresponds to a source moving upwards at $\sim$620 km s^{-1}. For comparision, at the same altitude the ion sound speed is typically 1.4–2.5 km s^{-1} assuming that O^+ is the dominant ion, and the Alfvén speed is about 900 km s^{-1}. The drift velocity estimated from the maximum observed frequency drift measured approaches

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*Department of Physics and Astronomy, Dartmouth College, Hanover, New Hampshire, USA that of the local Alfvén speed, but typical drift velocities < 10 km s^{-1} are closer to the ion acoustic speed assuming H$^+$ or O$^+$ ion composition.

The separation of fine structure features by a few hundred Hertz implies source regions vertically separated by as little as 100 meters, assuming generation where $f = 2f_{ce}$. The upper bound on the minimum bandwidth of 6 Hz restricts the vertical spatial extent of the source to as small as a few meters. The free space wavelength at 3 MHz is 100 meters, an order of magnitude larger than the vertical size of the source under the assumptions outlined above. Calvert, [1982] explains similar AKR fine structure narrow-band multiplet features in AKR fine structure with a feedback mechanism in which the path lengths at different places along an elongated cavity structure are equal to integer multiples of the wavelength of the unstable mode. Assuming a $2f_{ce}$ roar originating in a 50 km wide cavity at an altitude of 275 km, an approximately constant index of refraction requires the width of the cavity to change by nearly 40% between adjacent multiplet feedback paths in order to explain observed auroral roar multiplet fine structures with such a mechanism. (A constant width cavity requires too many wavelengths, and ultimately too wide a cavity, for the observed $\sim$200 Hz spacing between multiplets.) While such cavities are possible, the low growth rates predicted at these altitudes requires nearly all of the wave power to be reflected at the walls of the cavity. Needless to say, the challenge remains to theoretically explain a source of coherent radiation with a $f/\Delta f \sim 3 \times 10^5$ and a wavelength larger than the vertical extent of the source region.