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Farley-Buneman waves at large aspect angles

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The Farley-Buneman (FB) instability mechanism provides an excellent explanation for the presence of large amplitude plasma waves in the cm to few m wavelength range in the high latitude E region whenever the ambient electric field exceeds 20 mV/m. Observations suggest that the instabilities are observed at their threshold speed when they reach their largest amplitudes. This can be explained in terms of a combination of decreasing electric field and increasing aspect angle inside individual structures. However, another feature of observations is that linear theory predicts instability for aspect angles smaller than 1.5 degree, up to maybe 2 degrees even though there is plenty of evidence to show that large amplitude structures exist at aspect angles well beyond 2 degrees during Farley-Buneman events. We show that this observational feature is caused by the weak altitude dependence of the eigenfrequency, which forces the aspect angle to grow monotonically with time. This means that after the structures have reached their maximum amplitude, they continue to exist, but with the caveat that their aspect angle increases while their amplitude decreases. This allows damped modes at large aspect angles to be observed. However, as the aspect angle increases, the phase velocity of the waves will also change, although that change is actually a strong function of the wavelength of the structures. This means that we must assess the real and imaginary part of the eigenfrequency to query the Doppler shift of the structures and see how they compare with observations at different radar frequencies. To this goal, we have studied both the simple fluid isothermal dispersion relation, as well as the full kinetic dispersion. Our results for sub-meter wavelengths show that the phase velocity remains very constant at only slightly less than the ion-acoustic speed as the aspect angle increases. At larger wavelengths, the transition to zero phase velocity proceeds according to Vd/(1+psi), a result in agreement with the simple fluid predictions based on small growth rate considerations. The transition wavelength is controlled by the ion collision frequency.
We have used our calculations to determine how the phase velocity and the growth/decay rate depend on altitude (or collision frequency) and electric field conditions. The phase velocity calculations compare favorably with observations.

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