

Sunrise: A natural perturbation enables identification of propagation modes from distinct Doppler shifts

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Every day sunrise alters ionospheric electron density. Reflection height falls, reducing phase path length, seen as positive Doppler shift of the transmitted frequency. But the effect on propagation is complex. A glance at sunrise HamSCI GRAPE Personal Space Weather Station spectrograms will show many instances of multiple Doppler traces. Especially on paths over 1000 km at 10 MHz and above two broad groups are likely. First are distinct strong signal trace(s) from great circle paths. These fine traces have narrow spectral width. There may be times when transient loop-like double traces appear. High (Pedersen) rays and low rays with different paths, hence different Doppler, produce such loops. The different ionospheric paths of extraordinary and ordinary waves may result in different Doppler shifts. Despite this multiplicity straightforward ray tracing, e.g. PyLap, is well suited to modelling these great circle modes. Wide frequency spreads and low signal levels characterize the second group. These modes are two-hop sidescatter. Perturbation to height of reflection at sunrise is especially valuable for identifying sidescatter modes. North-south and east-west differences in height of reflection during sunrise lead to different Doppler shifts from different sidescatter regions. A worked example takes the GRAPE spectrogram for the 2640 km west-east path WWV to W2NAF, PA on 10 MHz on 8 April 2024. Over one hour there were six modes. PyLap 2D ray tracing easily identifies great circle one- and two-hop. A two-hop F2 then E (or Es) ray trace, with forward scatter not specular reflection, possibly explains the third. Combining 3D and 2D PyLap ray tracing suggests the sidescatter trace with greatest Doppler, from greater height change, was from north of the great circle path (Ontario). This trace merged with sidescatter from the south, with less Doppler, prior to two-hop great circle appearing. Sidescatter became forward scatter. More speculatively, the sixth trace, as descent started, was sidescatter from a region to the southeast that merged with that from the south.