The Importance of Elevation Angle Measurements in HF Radar Investigations of the Ionosphere

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1. Extended Abstract

Over the past several decades, HF radars in the SuperDARN network have been used extensively to measure plasma circulation in the Earth's mid to high-latitude ionosphere and support scientific investigations of the Earth's ionosphere and magnetosphere. Transmissions at these frequencies undergo ionospheric refraction and thereby enable signals backscattered by F-region ionospheric irregularities to return to the radar site. Unfortunately, the refraction that enables these irregularities to be detected makes it difficult to determine the ground range to these scattering volumes and the wavelength changes that result from this refraction, when undetermined, leads to underestimates of the Doppler velocity. For SuperDARN and other oblique backscatter radars, equivalent path methods are used to determine the ground range to points underlying ionospheric scattering volumes. This approach replaces the unknown refracted path with a straight-line path having the same initial elevation angle, α, and group range, L, as the refracted path. This path intersects a radial line extending from the center of the Earth to the point of intersection. The intersection is located at a virtual height, h, above the earth and the radial line passes through the actual scattering volume at a lower altitude along its path. These two lines and a radius line extending from the center of the earth to the radar site form an obtuse triangle, for which all sides and internal angles may be determined, if the initial or final α of the radar transmission and L are known.

While SuperDARN researchers have occasionally used α and L measurements to determine the ground range to ionospheric scattering volumes, in most cases the ground range is determined from measurements of L and one of two virtual models. Each virtual height model uses two or more single-valued, static functions to predict the value h that is associated with each measured L. Given the Earth radius, R, L, and h, each obtuse triangle and all internal angles are fully specified for the virtual height model that is used. Each model and measured L predicts specific values for α, β (angle of incidence on ionosphere), and γ (Earth-centered angle). These predictions are inconsistent with equivalent path methods, which require that α and L be independent variables.

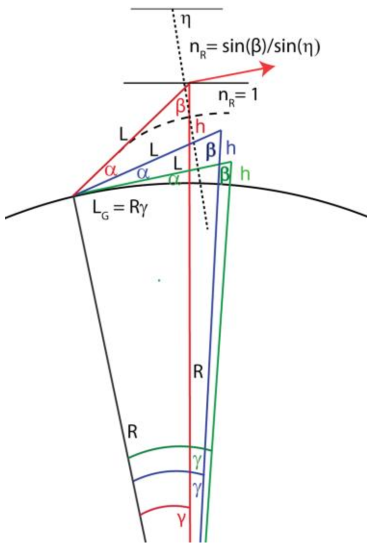

Figure 1. See text to right.

Figure 1 shows the major portions of three equivalent path obtuse triangles. All triangles have a common side of length R and an obtuse angle equal to π/2 +α. Ray tracing analysis through the time-dependent International Reference Ionosphere is used to identify all locations where rays are within 1° of orthogonal to the magnetic field. At each location, α and L were determined and used as inputs to the various geolocation methods. The triangle with two red sides was derived from α and L, whereas the triangles with blue and green sides were derived from L and h provided by its virtual height model. The respective internal angles of these triangles do not agree. Red α values are generally larger than those of the virtual height models, while red β and γ values are generally smaller. This means that the ground range, L_G, to the scattering volume and the refractive index, n_R, of the scattering volume are less for the red triangle than for the blue and green triangles. Comparisons of the L_G and n_R values predicted by these geolocation methods with L_G and n_R from ray tracing reveal that accurate equivalent path predictions require use of both α and L..

If we were to perform this analysis at a different local time, ray tracing analysis would most likely identify a different α associated with backscatter from range L. The red triangle would respond to this change; however, the blue and green triangles would not. They will always predict the same values of h for backscatter from L. The parameters α and L are required for accurate equivalent path predictions of L_G and n_R.