Estimation of high frequency wave fields using Gaussian ray bundles and Delaunay tessellation

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Predicting high frequency radar or communication system performance requires accurate channel estimation, including the effects of propagation through the ionosphere. Accurately modeling fading due to multipath, for example, requires information on the phase and amplitude of the individual signal arrivals between the two nodes. However, a single node may lie in a refractive shadow zone during some times, and in an area of focused energy during other times, due to the temporal and spatial variability of the ionosphere waveguide. Moreover, angles of arrival of the incident HF wave fronts also vary widely over time. We introduce a method of estimating incident HF intensity that combines 2-dimensional Gaussian-distributed ray bundles with Delaunay tessellation. Gaussian ray bundles, such as those used to study underwater acoustics, treat individual rays as normally distributed in cross section, thereby making it possible to estimate intensity in shadow areas by summing the field resulting from rays impinging on surrounding areas. In this method, intensity is estimated by the relative spreading of rays in a given bundle. Delaunay tessellation, in which points on a surface are sorted into 3-simplexes, produces a surface comprised of smaller facets with the constraint that the unique circle on which each facet's vertices lie contains no other points in the constellation. Additionally, a maximum size for each circle can be set. With these and other constraints, Delaunay tessellation combined with Gaussian ray bundles enables the estimation of properties of the wave field such as vector intensity over a large surface, for cases that may include multipath, shadow areas, or both. These parameter surfaces can then be used for estimating system performance parameters, such as probability of detection or channel spreading.