ON THE STATISTICS OF INTENSITY SCINTILLATIONS FOR A TWO-COMPONENT IRREGULARITY POWER LAW SPECTRUM

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We have recently extended the phase screen power law theory of ionospheric scintillation to include for the case where the refractive index irregularities follow a two-component inverse power law spectrum [paper to be submitted to Radio Sci, 2015]. A specific normalization was invoked to exploit the self-similar properties of the problem and achieve a universal scaling, such that different combinations of perturbation strength, propagation distance, and frequency produce the same results. Using this model, numerical quadrature was employed to obtain essentially exact solutions of the fourth moment equation governing the intensity variations resulting from propagation through two-dimensional field-aligned ionospheric irregularities. New asymptotic results for the strong scatter regime were developed and validated.

In this paper, we draw upon these asymptotic and numerical results to explain the development of the S_4 index and intensity correlation length as a function of scattering strength when the irregularity spectrum includes a spectral break. If the spectral break and Fresnel scale are well separated, we find that in weak to intermediate scatter regime S_4 and the correlation length follow the development of an unmodified power law with the same slope as the spectral segment containing the Fresnel scale. Effectively the intensity field develops as if the spectral break were not present. This is not surprising since when the scatter is sufficiently weak only those scales in the irregularity structure close to the Fresnel scale contribute to the intensity variations. As the scattering strength increases so does the range of spatial scales in the irregularity structure that contribute to the intensity variations. At a sufficiently strong strength of scatter, the development of S_4 and correlation length transitions to follow a new path of development characteristic of a two-component spectrum. In this regime, irregularity scales on both sides of the spectral break contribute to the intensity statistics. When the spectral break is not well separated from the Fresnel scale, irregularity scales on both sides of the spectral break contribute to the intensity statistics even in weak scatter. The intensity statistics reflect the presence of the break at any strength of scatter and the development of S_4 and correlation length is that of a two-component spectrum. In summary, depending on the scale separation between the spectral break and Fresnel scale, the intensity statistics do not “feel” the break until the scattering is sufficiently strong. We show that the transitional strength of scatter at which the spectral break begins to be felt is predictable from the asymptotic theory.

Uscinscki et al. [Proc. Royal Soc. London, 1981] came to a similar conclusion by noting that the presence of an outer scale does not affect the intensity statistics if the observer is sufficiently close to the screen. The results of our analysis generalize this notion to the case of an arbitrarily located spectral break. Moreover, by exploiting the universal scaling we can generalize the Uscinscki result for any combination of irregularity strength, frequency, and distance to the screen. We can therefore provide quantitative guidelines for predicting whether a general spectral break will be "felt" or not, and hence whether the asymptotic results for the unmodified or two-component models will more accurately reflect the results of an experiment for a given strength of scatter. This has important ramification for applications which use measurements of the intensity correlation length to infer the strength of scintillation when the observations are saturated.