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Radar Target Amplitude, Angle, and Doppler Scintillation from Analysis of the Echo Signal Propagating in Space

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Radar target scintillation is observed in every type of radar system and has generally been analyzed on the basis of the performance of specific types of radar systems. However, the target scintillation phenomenon, including Doppler scintillation, may be expressed as distortions of the radar echo signal propagating in space, independent of radar system parameters. In this form it is convenient for visualizing the overall effects on radar systems and how these effects are altered by the radar system parameters. Past literature has demonstrated the target angle scintillation as a distortion of the radar echo signal phase front. Extension of this approach by a Poynting-vector analysis of the radar echo signal from a complex source shows a corresponding deviation of the direction of power flow consistent with the phase-front distortion theory and target scintillation measurements as well as describing all other target scintillation characteristics. The analysis demonstrates that deviations in the direction of the echo signal power flow from a complex target can be so large that the apparent source falls many target spans away from the actual target location. This is demonstrated by both tracking radar and single-beam search-type radar experiments. Although the theoretical angle deviations approach infinite error in target location, radar parameters, such as the finite size antenna aperture which perform a space integration of the echo signal, impose practical limitations. Typically, when a complex target such as an aircraft subtends an angle approaching a few tenths of a beamwidth, the antenna aperture integration will significantly limit the rms angle scintillation. Furthermore, the ways in which intentional means, such as diversity techniques, may be employed to reduce the effects of target scintillation on a radar are observed in Poynting-vector analysis. The analysis of the echo signal propagating in space provides a readily visualized basis for derivation of the Doppler scintillation caused by the airframe (rigid body portion) of a complex target which spreads the Doppler over a finite bandwidth when it has random yaw, pitch, and roll motion typical of aircraft in flight. The derivation relates the Doppler scintillation to the angle scintillation

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and the random motions typical of aircraft targets. A typical aircraft target with Gaussian-distributed angle scintillation and Gaussian-distributed rates of random motion will have a spike-shaped Doppler spectrum described by the modified Hankel function K/sub 0/ where the parameters are determined from the values of the rms angle scintillation and the rms angular rates of random motion. These values can be closely approximated without extensive measurements on the target. Experimental results verify the theory. The expressions used to derive the Doppler spectrum may be modified to accommodate non-Gaussian distributed angle scintillation and rates of angle motion.

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