MEASUREMENTS OF SOUND FIELD STATISTICS NEAR THE GROUND WITH A LARGE OUTDOOR ARRAY

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Introduction

The statistics of a sound field propagating through the turbulent atmosphere outdoors near the ground depend upon the prevailing meteorological conditions, the ground topology and impedance, as well as the dynamics of the sound source. An understanding of these statistics is necessary to obtain effective sound field measurements, to realistically assess propagation models and codes, and design and predict the performance of acoustic remote sensing systems.

We explore some of these principles based on theory and measurements obtained with a large acoustic array developed at NRC. The array is unique measurement and research tool because of its large size (64 elements) and flexible geometry. The investigation distinguishes between line-of-sight propagation and the sound field within an acoustic shadow.

Coherence for Line-of-sight Propagation

Typical values for temporal coherence can exceed 10 seconds and tend to follow the relationship

$$t_0=(0.75C_n^2k_0^2R)^{-3/5}/V_\perp .$$

where C_n indicates the turbulence strength (and is of the order of 10^{-3}), R is the propagation range, and $V_\perp$ is the component of the wind velocity across the propagation path. Spatial coherence in the direction of propagation may be hundreds of meters but, transverse to this direction, it is on the order of a meter. The coherence between two tones separated in frequency by ω_0 and propagating simultaneously is essentially independent of the mean signal frequency. The frequency separation at which the coherence drops below 1/e varies as $R^{-1/2}$ at short ranges and as 1/R at longer ranges.

Coherence in an Acoustic Shadow Region

Temporal coherence in a shadow region follows

$$t_0=\sqrt{6}/2k_0\sigma_v\sin\theta$$

where k_0 is the source wavenumber, σ_v is the standard deviation of the wind speed (approximately 0.1 - 0.3 times the wind speed), and θ is half the scattering angle ($\sin\theta$ is typically about 0.1). Spatial coherence is much shorter in an acoustic shadow than for line-of-sight propagation. Within a shadow region, the coherence length in the direction of propagation may be as little as 10 meters and transverse to the direction of propagation it may be much smaller. Transverse coherence tends to be about twice the signal wavelength for higher frequencies. Frequency coherence decreases rapidly within the shadow zone boundary; signals separated by less than 20 Hz show little correlation at frequencies between 200 and 1000 Hz.

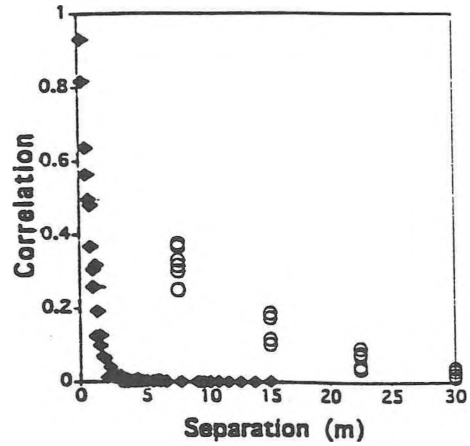

Figure 1 Spatial coherence in a shadow at 500 Hz, transverse (diamond) and longitudinal (circle) to the propagation direction.

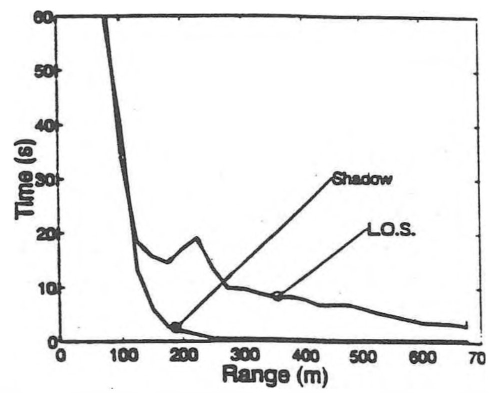

Figure 2 Temporal coherence for a 500 Hz tone for line-of-sight (L.O.S.) and acoustic shadow conditions.

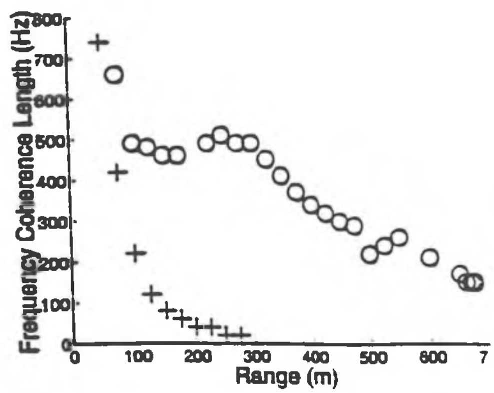

Figure 3 Frequency coherence length (bandwidth) for line-of-sight (circle) and acoustic shadow conditions (cross).