4.5B PARAMETERIZATION OF FRESNEL RETURNS

J. Rottger

EISCAT Scientific Association
P.O. Box 705
S-98127 Kiruna, Sweden

It appears appropriate to use the intensity correlation function $\rho(\tau)$ to investigate variations of a reflected signal component, $C_r{}^2$, and a scattered signal component, $C_s{}^2$, because it is determined by the relative motions, i.e., fluctuations of irregularities or structural changes.

An example of a correlation function $\rho(\tau)$ is shown in Figure 1. It can be separated into three parts. (1) A very fast drop between zero and the neighboring lag which is due to uncorrelated noise. (2) A smooth decrease at small lags up to a few seconds which is due to scattering. This decrease can be approximated by a parabola (equation (1)). (3) A rather slow fadeout which is due to Fresnel reflection and very gradually approaches zero correlation for longer lags.

The noise contribution (part (1)) has to be eliminated by normalizing the correlation function by means of the zero-lag value ρ' which follows from a parabolic approximation. As signal intensity variations are directly connected to turbulent variations in a scattering medium or the changes of a reflecting discontinuity, we can evaluate parts (2) and (3) of the normalized correlation functions in terms of characteristic structure parameters (e.g., FROST and BITTE, 1977):

(1) The microscale correlation time is defined as

$$\tau_e = \left[- \frac{1}{2} \frac{\partial^2 \rho}{\partial \tau^2} \right]^{-1/2} \tag{1}$$

The value of τ_e is given by the interception of the $\rho = 0$ axis by the parabolic curve fitted through $\rho(\tau)$ at $0 \lesssim \tau \ll T$ (see Figure 1). The microscale correlation time is a measure of the most rapid changes that occur in the fluctuations on the radar Bragg scale. The time τ_e is also called "coherence time" or "time to independence" (e.g., ATLAS, 1964), since this is the time after which the turbulent fluctuations at half the radar wavelength λ become statistically independent.

(2) The average persistency of a structure is given by the integral-scale correlation time

$$T_e = \int_0^T \rho(\tau)\, d\tau \tag{2}$$

where T is the length of the correlation function. The persistency T_e is a measure of the longest-lived coherence in structural behavior.

It can be shown that $\tau_e \sim \lambda/(4\pi\sigma_w)$, where σ_w is the rms deviation of the velocity distribution. In a similar way, the integral-scale correlation time or persistency T_e can be expressed by a characteristic length L and a velocity u, with which a reflecting structure is advected through the radar beam. We find $T \sim L/u$. This assumption is based on the Taylor hypothesis that the time scale for evolution of a structure of dimension L is so long that there is no

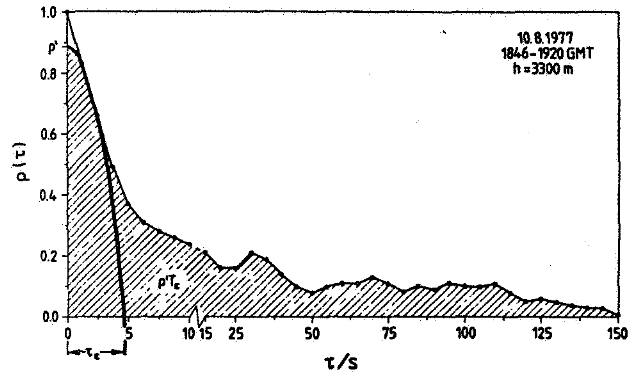

Figure 1. Intensity correlation function $\rho(\tau)$. The scaling of the τ axis is different for the lags $0\ s < \tau < 10\ s$ and $15\ s < \tau < 150\ s$; ρ' is the offset correlation at zero lag due to noise contributions; τ_e is the microscale correlation time, and the area $\rho' T_e$ determines the integral-scale correlation time T_e.

significant change during its advection through the radar beam. The persistency T_e is large for a slowly changing discontinuity and for minor contributions due to scattering, $C_s^2 \ll C_r^2$. If $C_s^2 \gg C_r^2$, the integral-scale correlation time will approach the microscale correlation time ($T_e \rightarrow \frac{2}{3} \tau_e$). In most realistic conditions, scattering and reflection are observed, i.e., $C_s^2 \sim C_r^2$. The correlation function then indicates a Gaussian shape approximated by a parabola near zero lag. Zero correlation is gradually approached for long time lags because of contributions from reflection (e.g., Figure 1). The integrals $I(\tau_e) = \int_0^{\tau_e} \rho \, d\tau$ and $I(T_e) = \int_0^{T} \rho \, d\tau - I(\tau_e)$ yield a rough estimate of the scattered and reflected contributions. We expect $I(T_e) \sim I(\tau_e)$ if $C_r^2 \sim C_s^2$. For $\tau < \tau_e$, $\rho(\tau)$ is essentially determined by turbulence scatter, whereas it is determined by reflection for $\tau > \tau_e$. An estimate of the scattered contribution can also be obtained by high pass filtering ($f > \tau_e^{-1}$) and an estimate of the reflected contribution by low pass filtering ($f < \tau_e^{-1}$) of the intensity time series.

RASTOGI and ROTTGER (1982) used a high-pass and low-pass filter procedure to separate the scattered from the reflected component. They defined a specularity index R which is the ratio of the rms outputs from the low-pass and the high-pass filters. This procedure of course needs an a priori definition of the cutoff frequencies of these filters. If $R > 1$, the reflected component is dominant; if $R < 1$, the scattered component is dominant.

Another most preferred way would be to evaluate the spectra as suggested by Rottger (this volume, p. 112). As mentioned there, the scattered contribution is the integral over the Gaussian background distribution, whereas the reflected contribution is the integral over the remaining spikes which are assumed to be caused by diffuse reflection.

REFERENCES

Atlas, D. (1964), Advances in radar meteorology, in: Advances of Geophysics, (ed. H. E. Landsberg and J. van Mieghem), Academic, New York, 317-478.

Frost, W. and J. Bitte (1977), Statistical concepts of turbulence, in: Handbook for Turbulence, 1, (ed. W. Frost and T. H. Mouldon), Plenum, New York, 53-83.

Rastogi, P. K. and J. Rottger (1982), VHF radar observations of coherent reflections in the vicinity of the tropopause, J. Atmos. Terr. Phys., 44, 461-469.