8.6B PROPERTIES OF ECHO SPECTRA OBSERVED BY MST RADARS

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INTRODUCTION

Turbulent scatter and Fresnel reflection are the fundamental echoing mechanisms to interpret the signals observed by MST radars (HARPER and GORDON, 1980). Turbulent scattered echoes provide information about the turbulence structure and mean flow of the atmosphere. Observational results with VHF MST radars, however, show the importance of Fresnel reflection due to the infinite gradient of reflectivity at the edges of a scattering layer. This condition is excluded for the weak fluctuation models but it is still possible to include the observed aspect sensitivity by assuming an anisotropic structure of fluctuations. This paper tries to give another explanation of the aspect sensitivity observed by MST radars. Spectral estimates by the widely used periodogram are related to a four-dimensional spectrum of atmospheric fluctuations with anisotropic structure. Effects of radar system such as antenna beam width, beam direction and FFT data length are discussed for anisotropic turbulent atmosphere. Echo parameters are also estimated.

PERIODOGRAM ESTIMATION

The Fourier transform of scattered echo, $Q(\omega)$, is defined as follows;

$$Q(\omega) = \int w(t)q(t)\exp[-j\omega t]dt \tag{1}$$

where $q(t)$ and $w(t)$ are the sampled data at pertinent altitude and the FFT window function, respectively. The periodogram of $q(t)$ is defined as the ensemble average of QQ^*.

$$<|Q(\Omega)|^2> = \iint \Phi(K,\omega)|H(K,\omega-\Omega)|^2 dKd \tag{2}$$

where Φ is a four-dimensional (space-time) spectral density which we have expressed as the product of a power-law spatial spectrum and a Gaussian temporal spectrum (ISHIMARU, 1978).

H represents the effects of the radar used for the observations. Radar frequency, antenna beam width, pulse waveform and data length of the FFT window determine the properties of H. LIU and YEH (1980) showed that the classical Booker-Gordon formula is valid when the condition $D/\lambda_F \ll \lambda/Lo$ is satisfied, where D and λ_F are the antenna beam extent and the Fresnel radius at altitude z, respectively. For anisotropic fluctuations, the effective horizontal length scale becomes comparable to the Fresnel radius, thus $H(K, \omega-\Omega)$ is computed to include the phase difference of incident waves in the scattering region.

Figure 1 shows an example of the calculated periodograms. Parameters for the calculation are given in the figure. The dotted line represents the temporal spectrum of $\Phi(K, \omega)$. It shows that the observed spectral width does not always agree with that of the temporal fluctuation.

PARAMETER ESTIMATION

We now discuss a moment dependence of periodograms on the beam width, beam direction and FFT data length.

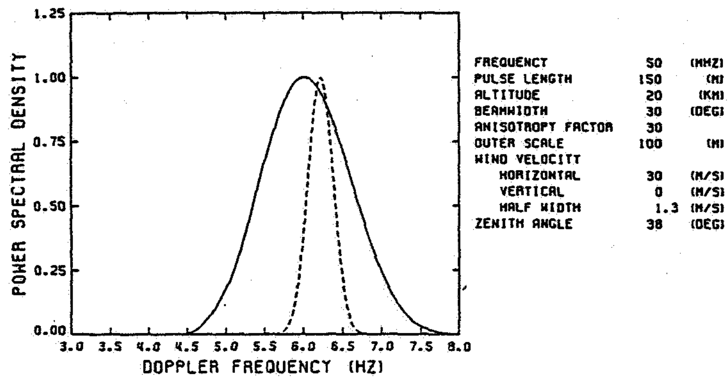

Figure 1. An example of estimated periodograms.

Figure 2 shows the zeroth moment (echo power) dependence on the zenith angle. When the anisotropy of fluctuations is relatively small, the angle of coherence cone is much wider than the antenna beam width, resulting in the echo power slightly dependent on the zenith angle. Results observed by the Jicamarca radar conclude, however, that the difference of echo power between the vertical and off-vertical (3 degrees from the zenith) beams is about several decibels (FUKAO et al., 1980). Our calculation suggests that the horizontal length scale of fluctuations is about a few tens times larger than that of the vertical direction.

For the first moment of periodograms, the estimation error increases for larger values of anisotropy with wider antenna beams. But the relative error is very small, thus it could be concluded that the effects of the radar system on thw Doppler velocity estimations are virtually neglected.

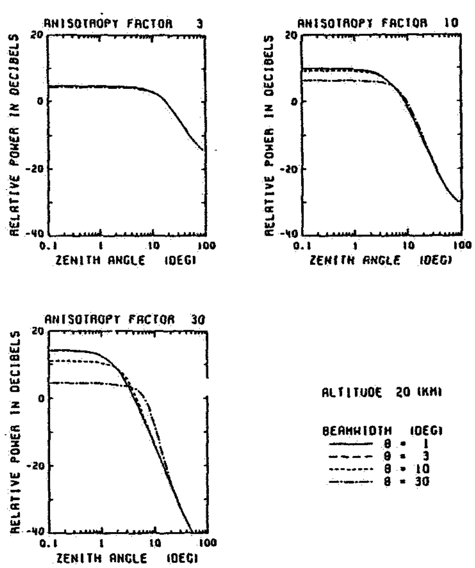

Figure 2. Echo power versus antenna zenith angle.

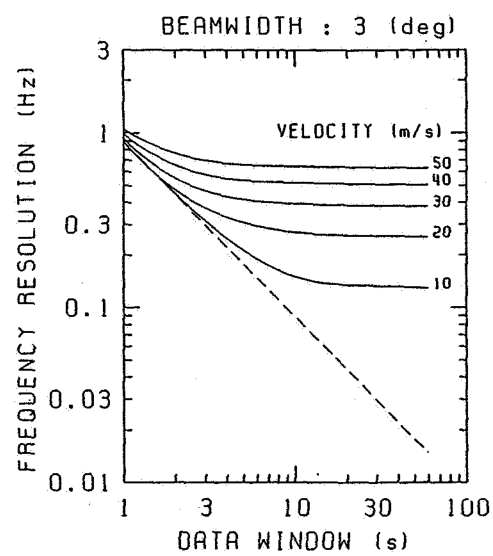

Figure 3. Frequency resolution versus FFT window length.

The bandwidth of H in the frequency direction determines the frequency resolution of periodograms, which then affects the estimations of the second moment. Figure 3 shows the relation between the spectral resolution and the time duration of FFT window. When the horizontal velocity of fluctuations is relatively small, the resolution is inversely proportional to the FFT duration. The resolution converges to a certain value that is determined by the beam width and/or wind velocity. This is due to the finite extents of scattering volume.

CONCLUSIONS

The effect of finite space-time extents is examined for spectral estimations or MST radar observations. An aspect sensitivity of scattered echo can take place in the case of a weak refractive index fluctuations with anisotropic structure.

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