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2.2A SIGNAL STATISTICS OF THE RADAR ECHOES - ANGLE-OF-ARRIVAL STATISTICS

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The statistical characteristics of radar echoes were investigated by several groups since the early days of VHF radar observations. Essentially, the power, amplitude and phase distributions as well as the distribution of power as a function of frequency (power spectrum analysis) were studied extensively. This led to a better, but not yet exhaustive, understanding of the processes leading to the VHF radar echoes from the lower and middle atmosphere, and it is now fairly well established that volume scattering as well as Fresnel scattering and reflection occur.

It was noted earlier that Doppler spectra, measured with a vertical antenna beam, are characterized by essentially two different kinds of distributions (e.g., ROTTGER, 1980; GAGE et al., 1981), one has a very narrow and the other a broad spectral width. The former is accepted as due to reflection whereas the latter is due to scattering. It can happen that both kinds of spectra are observed simultaneously, as shown in Figure 1. Superimposed on a fairly broad Gaussian signal spectrum, very narrow signal spikes are evident. The spikes can be even more distinctly seen in the spectra of Figure 2, computed for a 6-times shorter integration period (80 s).

Since the height resolution during these experiments was 150 m and the signal amplitude changed drastically between adjacent range gates (Figures 2 and 3), it is very unlikely that these echoes are due to volume scattering. They are rather due to reflection from a thin sheet or step in refractivity, being much narrower than the range gate of 150 m (reference also HOCKING and ROTTGER, 1983). The spikes in the spectra of Figure 2, however, cannot be explained by reflection from a flat and smooth discontinuity. The sheet must be rather tough or corrugated, and reflection from several subregions of the sheet is expected, as shown in Figure 5. Because the spikes occur at different Doppler frequencies, the subreflectors have to be assumed to move with different radial velocities.

To experimentally verify this reasonable assumption, it is proposed to measure the angle of arrival of the different signal returns. One can here make use of the essential advantage that the spikes can be filtered in frequency (called Doppler sortening or sharpening). By means of the cross-spectrum analysis with the interferometer technique (measuring phase differences between spaced antennas, as described in the paper "Improvement of vertical velocity measurements" by J. Rottger, Chapter 3, this volume), their angle of arrival can be measured. This will allow determination of the distribution of the angles of arrival. Knowing the Doppler shift and the arrival angle of the whole set of returns (sorted by Doppler frequency, i.e., radial velocity) yields a set of $n = 1,\ldots,N$ equations (N = number of evaluable spikes):

$$V_{rn} = V'_{rn} + U_o \cos \delta^*_n + W_o \sin \delta^*_n.$$

The solution (e.g., regression analysis) will lead to the mean horizontal and vertical velocities, the tilt and the aspect sensitivity of the illuminated area. It also would support the hypothesis that the reflecting sheet is

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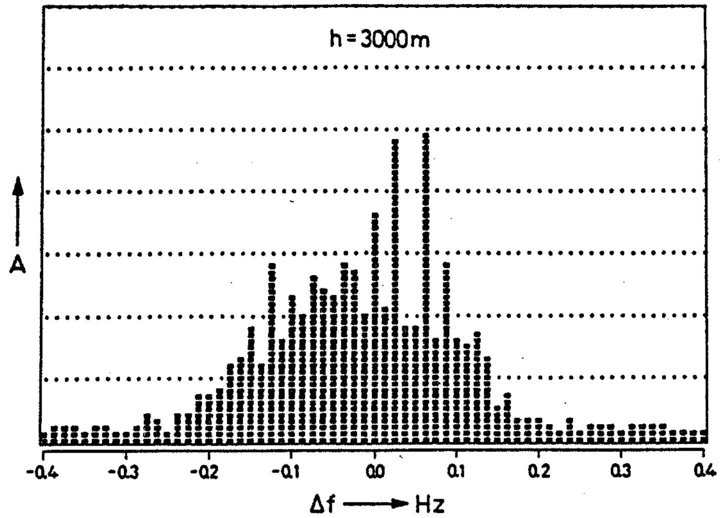

Figure 1. Doppler spectrum of signal measured with vertical antenna beam and 150 m height resolution, averaged over 8 min (from ROTTGER, 1980).

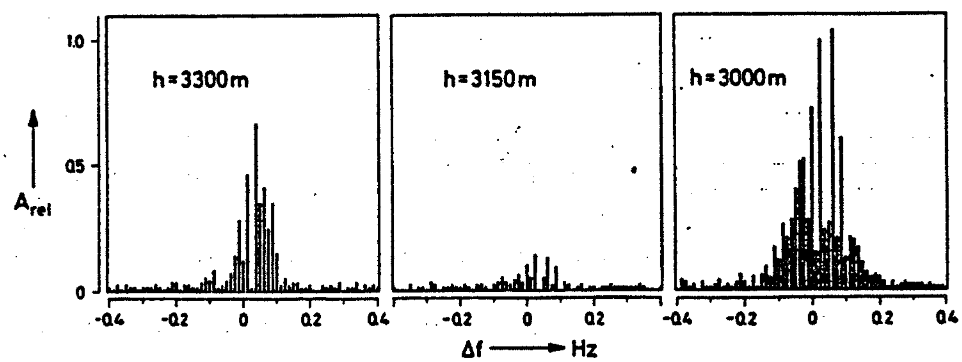

Figure 2. Doppler spectra computer from an 80 s time series.

corrugated. The determination of the mean velocities by this method also allows testing of Brigg's hypothesis (1980) that the Doppler beam-swinging method (DBS) is in principle similar to the spaced antenna-drifts method (SAD).

Measuring the variation of the arrival angle distribution as a function of time will also allow testing of the hypothesis (GAGE et al., 1981) that the specular reflection point moves with respect to different phases of gravity waves which may modulate the reflecting sheet. There may even be atmospheric waves of different periods involved in this process, as indicated in Figures 3 and 4. The amplitude time series in Figure 3 shows evident oscillations at periods of about 10 s, which may be because of a Benard cellular structure of the reflecting sheet moving through the radar beam, causing focussing and defocussing (SHEEN et al., 1984), and correspondingly also changes of the arrival angle (to be experimentally proved). The long-period (≈10 min) oscillation seen in the Doppler spectra of plot of Figure 4 also causes a varia-

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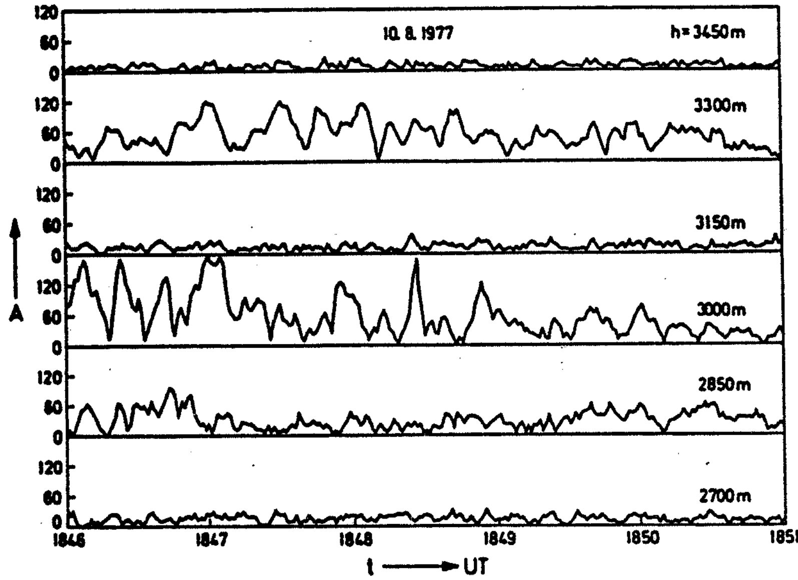

Figure 3. Amplitude time series for different height range gates.

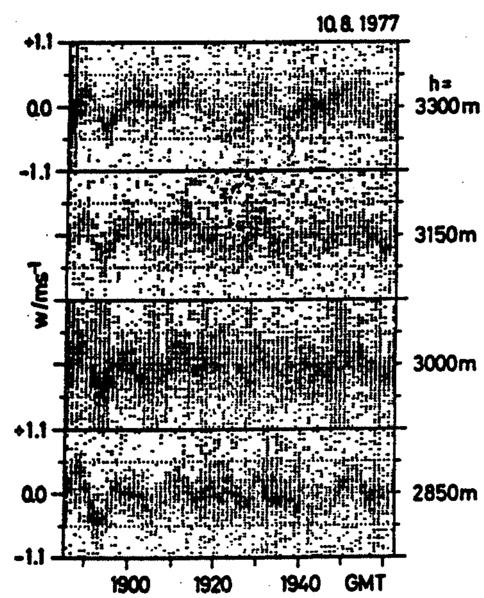

Figure 4. Doppler spectra plots (from ROTTGER, 1980).

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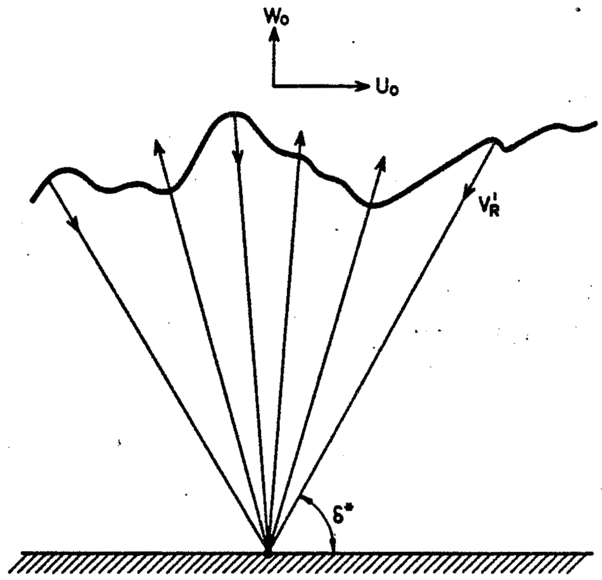

Figure 5. Reflections from sub-areas of a corrugated sheet of refractive index change, moving with the mean horizontal velocity U_o and the mean vertical velocity W_o; additionally a random (turbulent) component V_R' (due to fluctuations of U_o and W_o) is assumed.

tion of the signal amplitude. The period of the amplitude variation would be half the period of the velocity oscillation if the specular point moves out of the antenna beam (GAGE et al., 1981), but it should be equal to the wave's velocity period for focussing/defocussing. A long-period variation of the amplitude is also evident in Figure 3. The measurement of the distribution of arrival angles will yield additional information on these two effects.

REFERENCES

Briggs, B. H. (1980), Radar observations of atmospheric winds and turbulence: a comparison of techniques, J. Atmos. Terr. Phys., 42, 823-833.

Gage, K. S., D. A. Carter and W. L. Ecklund (1981), The effect of gravity waves on specular echoes observed by the Poker Flat MST radar, Geophys. Res. Lett., 8, 599-602.

Hocking, W. K. and J. Rottger (1983), Pulse length dependence of radar signal strengths for Fresnel backscatter, Radio Sci., 18, 1312-1324.

Rottger, J. (1980), Reflection and scattering of VHF radar signals from atmospheric refractivity structures, Radio Sci., 15, 259-276.

Sheen, D. R., C. H. Liu and J. Rottger (1984), A study of signal statistics of VHF radar echoes from clear air, to be submitted.