4.3.2 COMPARISON OF MEDIUM FREQUENCY PULSED RADAR INTERFEROMETER AND CORRELATION ANALYSIS WINDS. 2.

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INTRODUCTION

The preceding paper compared the mean instantaneous velocity of a group of scatterers with those found from correlation methods and concluded that it agreed well with the apparent velocity (which assumes a rigid isometric diffraction pattern on the ground). In order to test whether the chosen Doppler peaks represent localized scatterers in motion, as opposed to some sort of integrated composite, an attempt has been made to determine the change in position of single "scatterers" over a series of sequential records.

From Figure 6, in Paper 1, it can be seen that single scatterers moving with a constant horizontal velocity have the property that their Doppler frequency/radial velocity varies linearly with time, and has the same slope no matter where the scatterer is physically (this assumes constant range rather than constant height, but is a good approximation near the zenith). Also, assuming isotropic scatter, the power should be roughly constant, apart from transmitter antenna beam width considerations.

EXPERIMENT AND ANALYSIS

This experiment, unlike Paper 1, employs a four-antenna system (Figure 1) which has 1 degree of freedom in phase. Due to equipment limitations N-S linear transmission and E-W linear reception are used. The Doppler frequency peak selection criteria are that at least two of the four power spectra should have a local peak, and that the normalized phase discrepancy,

$$N\phi D = \left| \sum_{i=1}^{3}(\phi_i - \phi_4) / \sum_{i=1}^{3} |\phi_i - \phi_4| \right|$$

should be less than 0.3. An relative power criterion similar to that of Paper 1 is used. Since there are four antennas, the basic time step is 4/15 sec. The record length is 256 points (approx. 68 sec).

EXPERIMENTAL DATA

The raw data consist of half-hour lengths of complex amplitudes in which the receiver gain setting is constant at a given height (i.e., range gate). The records are spaced by 72 sec, giving ∿22 records per run. After scatterers have been identified, they are collected in height (rather than range) bins and plotted. Because different ranges, as originally measured, may have different gains, the power is defined to be the average peak power relative to the maximum spectral power in the original spectra. Plots are made of the position of the scatterers in each nominal height bin (which may include several range gates).

Figure 2 is the only example found so far in which moving "scatterers" can be perceived. The dashed line separates scatterers with +ve and -ve radial velocity. Also shown on this diagram are the vector displacements expected between records from the simultaneous 3-D and 2-D (horizontal) velocity vector fit to all scatterers in the half-hour, and that found from the real-time wind system ("true"). [The sense of in-phase (I) and quadrature (Q) signals was determined from this figure, and this is the easiest way because reversing I

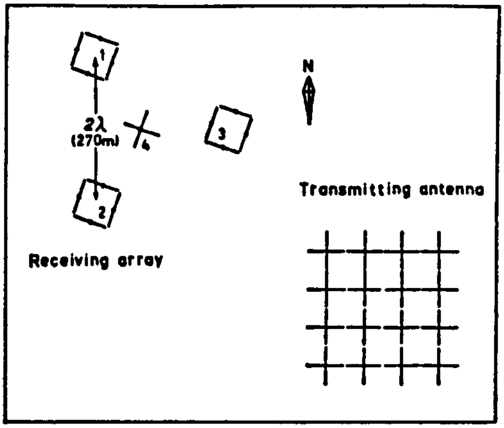

Figure 1. Transmitting antenna and 4 antenna receiving array.

and Q flips the scatterer azimuths by 180° but also changes the sign of the radial velocity; so the horizontal velocity is unaffected.]

The letters A, B, C,....,L show the positions of scatterers in successive records, and the size indicates their strength (~8 dB full range). The two sequences of interest are A-B-C and E-F--H(although there are two possible candidates for H in the latter). The position of C is uncertain because it is very near the zenith, and thus more affected by small phase errors in the system. Table 1 lists the characteristics of these particular scatterers.

With only one such example, speculation is easy; for example, suppose that the signal is not from an isolated point scatterer, but is a moving reflection point on a scattering layer perturbed by a wave. This would explain why the two sequences follow almost the same path. The period of the wave (the time between "B" and "F") is then 4 x 72 sec (= 5 min), and the wavelength can be estimated from the horizontal speed (~53 m/s, found from "A" assuming that the radial velocity is totally due to the horizontal phase velocity of the wave) to be 15 km. The fact that the direction doesn't agree with that of the "wind" also suggests a wave. Missing elements of sequences may be a result of a patchy scattering layer, which is moving with the background wind.

This is a very simple model, one would actually expect the reflection point to move relative to the wave as it passes over; but these complications will be left for future work.

Figure 3 shows a case in which the scattering seems to be coming from the same location (E-region heights) for the full half-hour. A stable wave perturbation in a "sheet of tin" could produce this effect provided that the ground pattern wavelength, λ_ω, was of the order of several times the array spacing, D, and the ground phase speed, V_ω, sufficient to give a non-zero Doppler frequency in the spectrum. Approximate values for these are given by:

$$\lambda_\omega \simeq \frac{D}{\sin(\text{zenith})} \quad ; \quad V_\omega = f_D \lambda_\omega$$

where f_D is the Doppler frequency; however, in this case, there should also be a peak with the opposite Doppler frequency 180° away in azimuth. Another

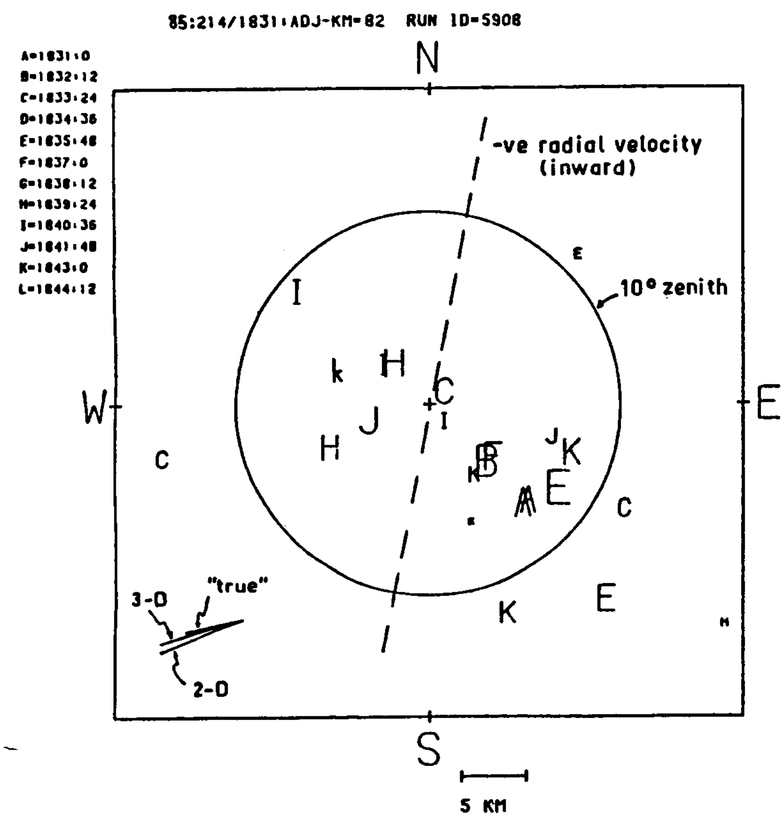

Figure 2. Scatter location over a series of short records, separate letters represent selected Doppler peaks, "+" is the zenith, 5 km distance scale is shown at the bottom. Expected displacements per record for 3 different wind estimates are shown at the bottom left corner.

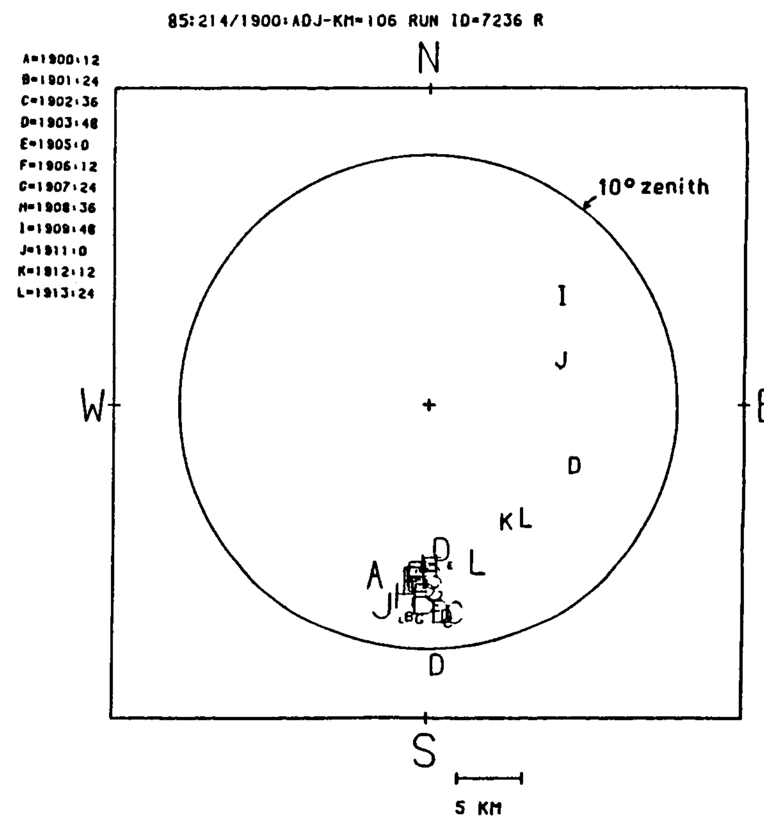

Figure 3. An example of a series of records in which the scatterers seem to be stationary in space and time. The radial velocities in the group are all outwards (see text).

TABLE 1

Calculated powers and positions of the selected Doppler peaks plotted in Figure 2 (all from the 82 km height gate). "Norm." is the normalization factor from the mean power in the original raw amplitudes. "Pmax" is the maximum spectral power (after normalization) in any single antenna spectrum, "Pwr" is the mean power (over all antennas) at the selected Doppler frequency. NϕD is the approximate normalized phase discrepancy.

Time	Plotted symbol	Norm. (dB)	Pmax (dB)	Pwr (dB)	V-rad (m/s)	Zenith (deg.)	Azimuth (Deg E of N)	NϕD
1831:00	A	41.6	-3.2	-4.8	-6.92	7.3	135.5	0.15
	A			-5.4	-5.93	7.4	133.2	0.15
1832:12	B	43.7	1.7	1.0	-1.98	4.3	134.3	0.05
1833:24	C	38.2	-0.2	-1.8	-0.99	1.1	49.5	0.05
1834.36	D							
1835:48	E	42.9	-1.8	-2.6	-8.90	8.3	122.3	0.15
1837:00	F	42.2	-1.1	-2.9	-3.96	4.4	128.9	0.15
1838:12	G							
1839:24	H	41.0	-1.4	-2.6	0.99	2.9	-38.5	0.05
	H			-3.8	6.92	5.7	-112.7	0.25

possibility is a tilted totally reflecting layer (about 7° tilt), but this cannot explain the non-zero Doppler frequency (median = ∿5 m/s); the scatter location should either move ∿ 3 km horizontally every record, or move out of the height gate radially within ∿ 10 min, and it does neither. A gradual electron density change below the height of reflection would create a Doppler shift, but it requires a very large change (which would also affect the reflection height) to get 5 m/s.

Something like a large-scale distortion of the atmosphere which "high lights" individual scatterers by focussing or tilting them as they pass through at the background wind speed is required to explain these data -- the scatterers are moving, but they are only seen in one direction.

CONCLUSIONS

The lack of success in tracking individual scatterers seems to suggest a short lifetime (as found by JONES, 1984). If this is the case, then the present experiment is not able to resolve the difference found between the correlation analysis "true" velocity and the interferometer value. On the other hand, it appears that the interferometer may be of some use in tracking waves.