3.2A CRITERIA FOR OPTIMUM SPACING OF SPACED ANTENNAS

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INTRODUCTION

There are many factors affecting the spaced antenna drift results, only one of which is antenna spacing. Generally, good results are obtained at MF for receiver antenna spacings of 1-1.5 λ, and at VHF (e.g. SOUSY) for spacings ~6λ. Since one of the factors, local atmospheric/ionospheric conditions, are difficult to predict, this paper will be restricted to a short discussion of relevant factors, and methods for comparing various antenna/analysis configurations.

"Optimum" may mean different things; for example;

(1) the most accurately determined lags for peak cross correlation
(2) the most consistent wind vectors, e.g. for small time differencces
(3) the least biased speed determination, based on theoretical considerations
(4) the most wind vectors
(5) the most accurate winds (by comparison with another "accepted" technique)
(6) the fastest wind vectors, i.e. shortest record lengths.

These may depend to a greater or lesser extent on the experimental system parameters, such as:

(1) transmitter antenna aperture
(2) transmitter pulse width and power
(3) receiver antenna aperture (physical size)
(4) receiver antenna spacing (including possible rf coupling)
(5) sampling rate and raw data integration
(6) record length
(7) noise level
(8) type of correlation (amplitude, hybrid bit-amplitude, or bit)
(9) rejection criteria (lower limit on acceptable peak correlation, normalized time discrepancy)
(10) analysis method; apparent or true velocity, and type of analysis (e.g. graphical, Gaussian fit to correlations, 6 point methods).

Some of these latter, pertaining to antenna systems, are discussed next.

EXPERIMENTAL FACTORS

Apparent velocity (V_{ap}) depends just on the lags, t_{max}, for peak cross correlation between receiving arrays, whereas true velocity, V_{tr}, accounts for average pattern scale and elongation as well as pattern decay rate (characteristic time). Larger pattern scales lead to wider correlations, and longer decay times to greater peak correlations. Because of statistical fluctuations, the t_{max} are less accurately determined for wide cross correlations, and it may be necessary to increase the absolute lag to reduce these errors (by increasing the antenna spacing, for example).

The transmitter beam width has a theoretical effect on the ground pattern scale, but in practice larger scales are found at Adelaide (wide beam) than at

Saskatoon (narrow beam); so it is likely the effective beam width is usually determined by the aspect sensitivity of the scattering process (although receiver spacing and analysis also seem to play a role). Increased transmitter pulse width and power lead to greater signal-to-noise ratio. Tests at Saskatoon for ~1 hr of data showed no obvious difference in quality (NTD distribution) between 20 μs and 50 μs pulse data, although the latter produced more data (presumably because good scattering layers were spread over several height gates).

The important characteristics of the receiving antennas: spacing, physical size, and rf coupling including any coupling in the feeder cables), can bias the measured speeds and pattern characteristics. A two-hour data set using the "Y" antenna array (Figure 1) at Saskatoon was analysed for both large (2λ) and small (1.2λ) spacing. Figure 2 shows that there is no significant bias between speeds, however larger pattern scales and characteristic times were found for the large spacing. A similar result was found in a comparison between the 1.2λ and a separate 1λ array over several weeks of daytime data.

Physical size of the antenna array implies a spatial average, in some way of the ground pattern. If the space between different receiving arrays is filled with antenna elements, a simple 1-D calculation with a rigid pattern, Gaussian correlation function, and the unrealistic condition that all scattered power arrives in phase, shows that the measure V_{ap} ($V_{ap} = V_{tr}$ in this case) can be too low by ~7%, independent of pattern scale. A similar 2-D simulation (but non-rigid pattern) supports this figure. The reason appears to be that the average correlation is weighted towards the higher values of correlation due to elements in different arrays which are close to each other; and so the "effective" receiver spacing is actually smaller than that used to calculate the velocity. The 2-D simulation also shows that pattern scales are

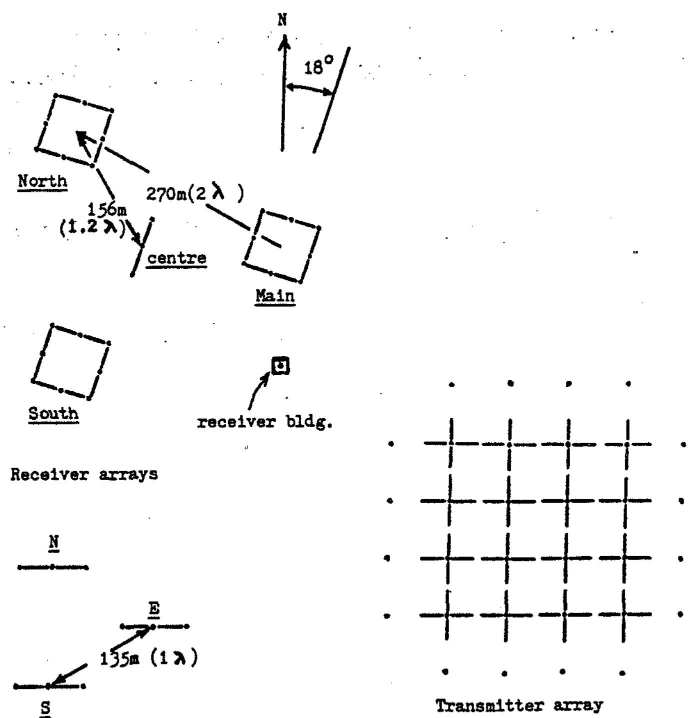

Figure 1. Antenna systems, main site (Saskatoon).

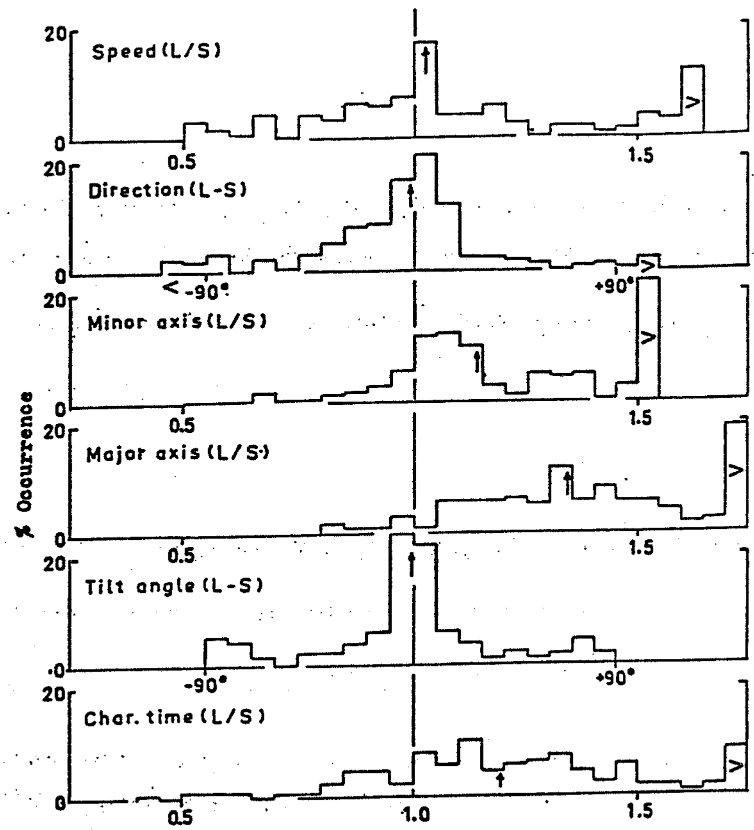

Figure 2. Comparison between FCA parameters for large spacing (2λ) and small spacing (1.2λ) arrays.

larger for a "filled" aperture antenna system (by ~20%), but the characteristic times are virtually unaffected (possibly because of the unrealistic condition on phase).

Coupling of antenna elements may be a problem, particularly at MF where the spacing is of the order of the rf wavelength; however, the 1-λ array (see Figure 1) mentioned previously, where the single dipole elements are not arranged for optimum isolation (-16dB coupling between two elements, phase shift unknown) shows negligible bias on the measured speeds in Figure 3. (The isolation between elements of the 1.2-λ array is better than 40 dB). A simulation for <u>in-phase</u> coupling of -20 dB shows that the measured speeds should be too high by ~20%, the pattern scales too high by ~30% and the characteristic times too low by ~5% on the average, depending on the input pattern characteristics. None of these, except the last, is seen in the 1-λ array data, and this might be due to spacing.

These simulations have yet to be done for complex amplitudes; however it is first necessary to investigate whether antenna elements hooked directly in parallel (as is the usual practice) add amplitudes in the same way as a power combiner.

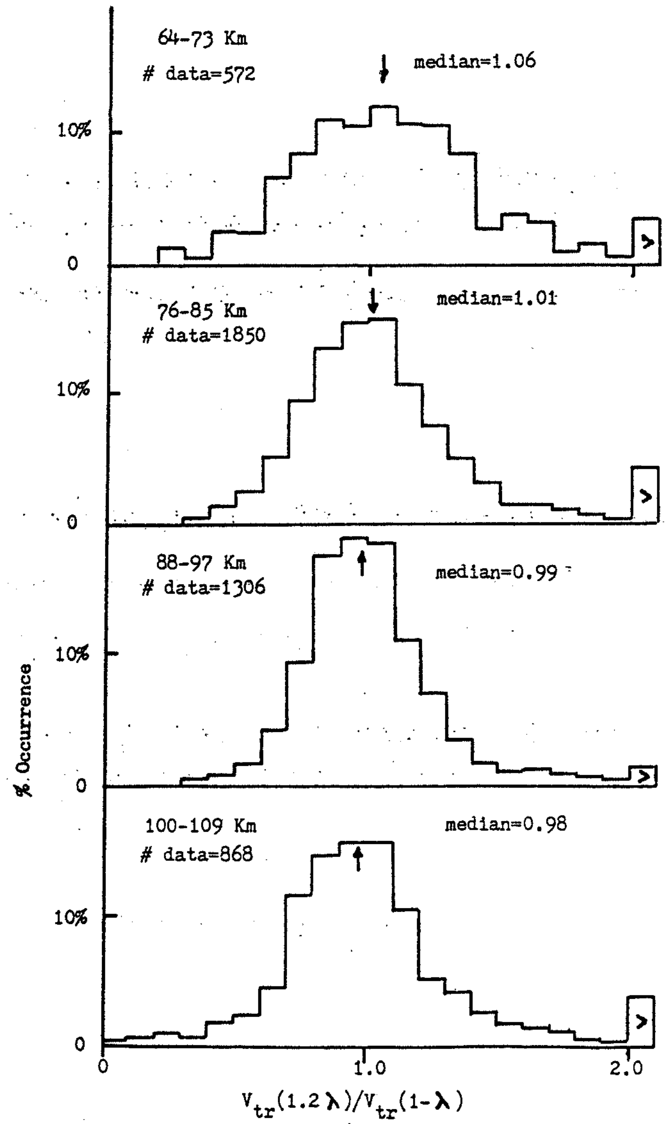

Figure 3. Speed comparison between the 4-antenna, 1.2-λ array and the 1-λ array. Selected days in Jan-Feb 1984. Bit correlation used in real-time analysis. 10 μs transmitter pulse.

METHODS FOR COMPARING DIFFERENCES IN LOCATION/HARDWARE/SOFTWARE

The most useful parameter is the normalized time discrepancy, NTD. If t_{max} are the lags for peak cross correlation for the i^{th} receiver pair, and the receiver pair vectors form a closed loop, the $\Sigma\, t_{max} = 0$ for a moving pattern. Distribution of the NTD,

$$NTD = \left|\Sigma\, t_{max_i}\right| / \Sigma \left|t_{max_i}\right|$$

are useful for comparing with the random t_{max} case, or with other antenna/analysis configurations. An example is shown in Figure 4. The NTD distribution depends on ionospheric conditions as well as spacing (which affects the magnitude of peak correlation), and defines the "quality" of the data (i.e. the fraction of the t_{max} data which may be attributed to moving patterns. In general, the larger the receiver spacing, the worse the NTD distribution -- since some of the "wanted" peaks fall below the magnitude of spurious peaks.

Other useful distributions are the angle difference and the normalized vector difference, $|(\overline{V}_1 - \overline{V}_2)/(\overline{V}_1 + \overline{V}_2)|$, where the wind vectors are closely separated in height or time, which are a "consistency check" on the data. These are found to depend strongly on the NTD distribution (although there is no direct theoretical connection) and so do not add much information when comparing basic experimental parameters.

CONCLUSIONS

The best advice for anyone setting up an MF radar system is to try an initial receiver antenna spacing of 1-1.5λ (using single dipoles and light masts), determine how much of the data is acceptable through the NTD distribution, and if too much is lost then adjust the spacing accordingly, based on examination of the cross correlations.

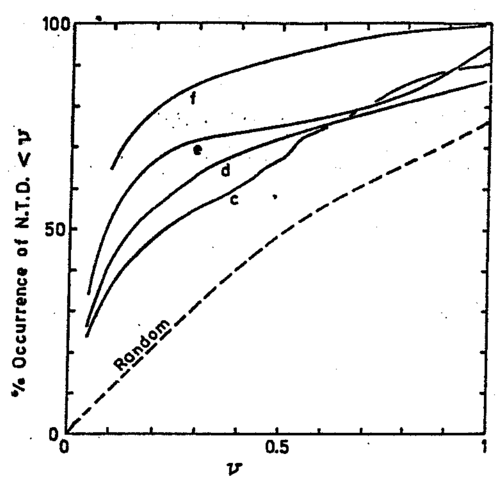

Figure 4. NTD distributions for small amounts of data for Saskatoon (c=2λ array. d=1.2λ array), Adelaide (f) and Ottawa (e).