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EFFECTS OF SPATIAL FILTERING, PREFILTERING, AND ALIASING IN MEASUREMENTS FROM APPLIED TECHNOLOGIES' SONIC K-PROBE

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The Applied Technologies' Inc. (ATI) K-probe measures wind components along three mutually orthogonal axes separated spatially from each other to minimize flow distortion errors. The sonic anemometer samples the wind at a 100-Hz rate but constructs 0.1-s (10-point) non-overlapping block averages to provide. a 10-Hz data train for internal processing. This digital prefiltering is designed to minimize the effects of aliasing high-frequency spectral energy back into the region below the Nyquist frequency (5 Hz). The internal processing consists mainly of corrections for transducer shadowing error in the two horizontal wind measurements and correcting the sonic temperature, measured along the vertical velocity path, for cross-wind contamination. No shadow corrections are applied to the vertical velocity (w) component because of the low wind inclination angles typically encountered near the surface.

In this note all factors affecting the sonic anemometer spectral response are examined to arrive at a final form for the measured w spectrum (the only one spared the transducer Shadow correction). The processes are easy to demonstrate graphically on log-log paper where the multiplication process translates to simple addition of distances on the graph

We start in Figure 1 with an idealized -5/3 spectrum (I) extending from 1 to 100 Hz. The original 100-Hz sampling aliases the energy above 50 Hz primarily into the region from 10 to 50 Hz. The energy near the Nyquist frequency is raised by a factor slightly above 2, if one includes the second and third folds. But this spectral distortion is too far removed from the 5-Hz Nyquist frequency in the 10-point block-averaged output to affect the final spectrum.

Spatial averaging for the 15-cm path has only a very small effect at frequency $f < 5$ Hz. The transfer function in Figure 2 corresponds to the curve for w for a wind speed of 5 ms^{-1}. The half-power point falls approximately at a wavelength of 15 cm (the path length), or a frequency of 33.3 Hz. The spatially averaged spectrum (II) in Figure 1 represents the form for the 100-Hz data train.

The 10-point block averaging can be broken down, for the purpose of illustration, into two separate steps: (1) passing a 0.1-s moving average across the spatially averaged spectrum, and (2) picking points from it 0.1 s apart. The first process is represented by a $\sin^2 \pi f \Delta t/(\pi f \Delta t)^2$ function, Δt being 0.1 Hz, in our case (Figure 2), and the second by aliasing in the 1-5 Hz range. Their effects on the spectrum are represented in Figure 1 by curves III and IV. The departure from the original spectrum is the hatched area in Figure 1. Also shown, for comparison, is the spectrum (V) one can expect in the absence of any prefiltering, i.e., from 0.1-s grab samples of the vertical velocity field (Figures 1 and 2).

The advantages of prefiltering are twofold:

(1) It greatly reduces the energy aliased into the 1-5 Hz spectral range, making it easier to identify the onset of the -5/3 power law. (The spectrum can be corrected, if needed, for the droop in that region.)

(2) It attenuates potential noise contributions above 50 Hz that might fold back into the 1-50 Hz band. (It will have no effect on those that appear below 1 Hz.)

For the longitudinal (u) and lateral (v) spectra, one can safely assume that the spatial averaging effect, at least at $f < 5$ Hz, will not significantly differ from that for w. However, the combined effects of transducer shadow correction and coordinate rotation will add some spurious energy above 1 Hz, essentially eliminating the droop apparent in the w spectrum. No corrections are recommended for the u and v spectra.

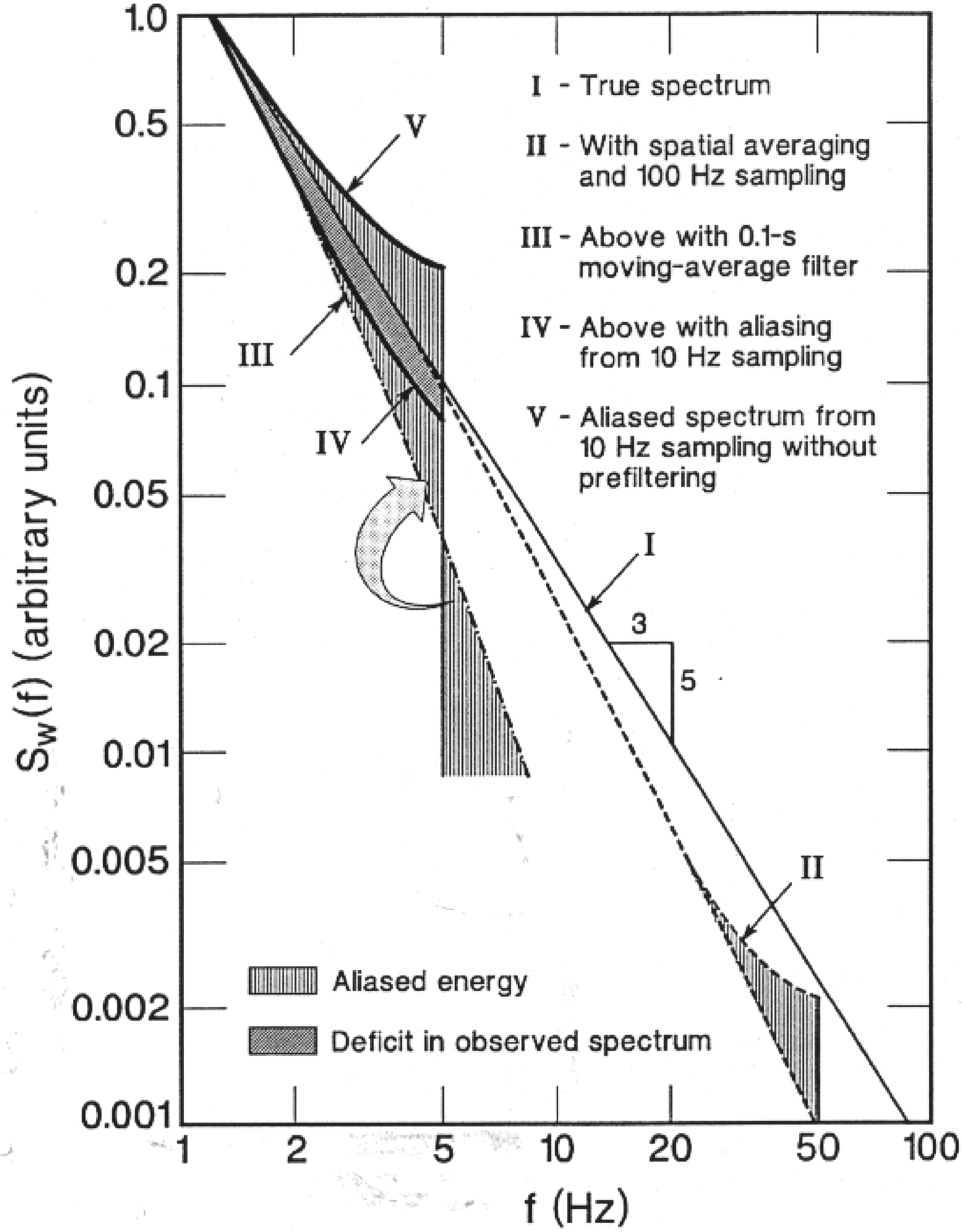

Figure 1. Effects of spatial averaging, digital prefiltering and aliasing on velocity spectral measurements with the ATI sonic K-probe.

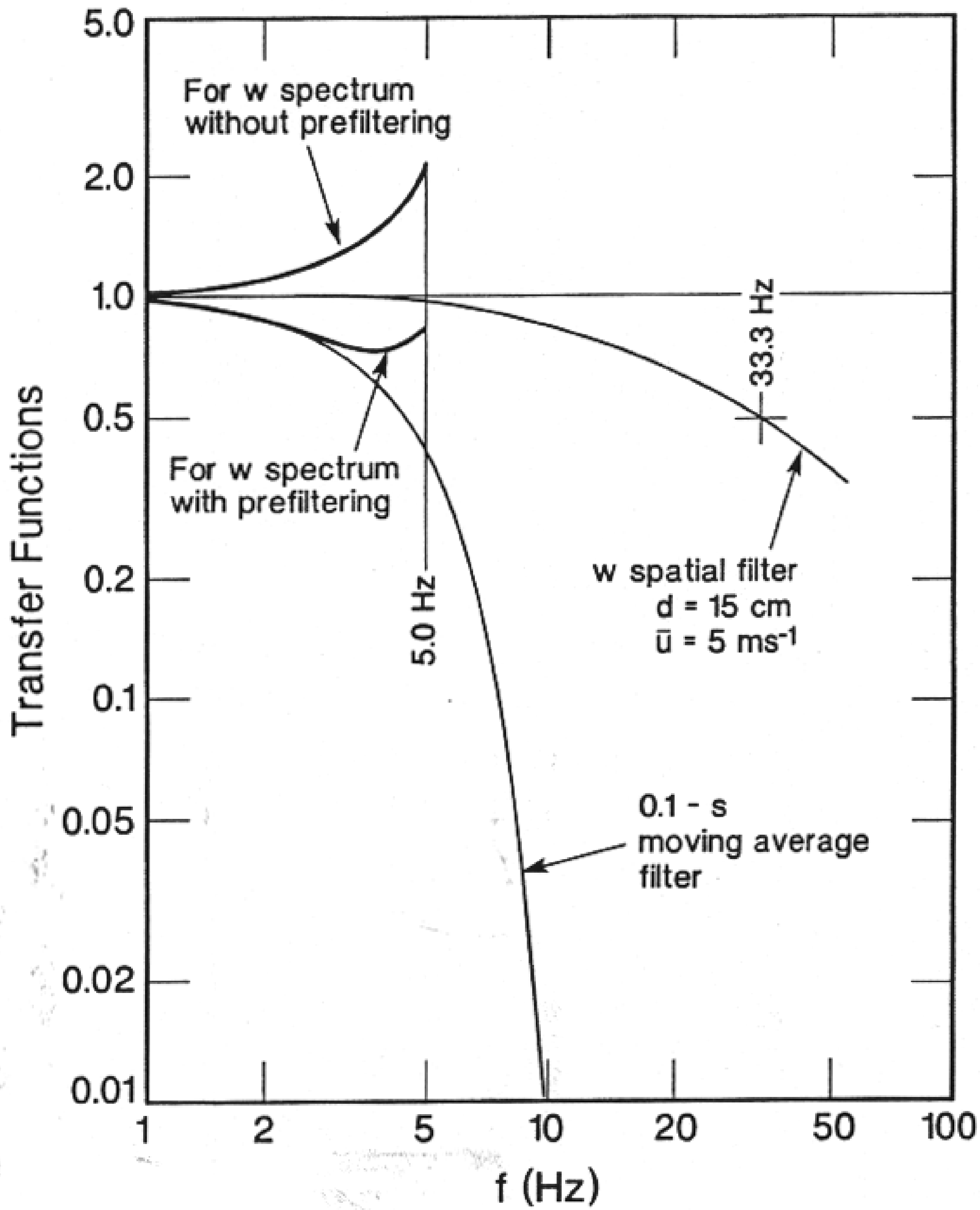

Figure 2. Transfer functions representing the effects of spatial averaging in *w*, digital prefiltering and aliasing.

NOTE UPDATE

Later instrument designs have also taken into account the shadow correction of the vertical velocity (w) component, even though it is considered minimal.