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EXPERIMENTAL AND THEORETICAL DOPPLER-LIDAR SIGNATURES OF AIRCRAFT WAKE VORTICES

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The DFVLR laser Doppler anemometer (LDA) is a CO_2 cw homodyne system designed for boundary-layer wind measurements. During the last three years, it was mainly used in the wake-vortex program at Frankfurt airport for determination of vortex strength, transport, and lifetime. At 12th ILRC, 1984 we have reported in detail on the strategy for that special type of measurements and have presented single experimental results [1]. Therefore, our paper will start with a short summary of the data concerning questions of air-traffic control.

In addition to the experimental activities a computer model describing wake-vortex behavior has been installed. It allows us to compare the measured data with the hydrodynamically predicted quantities. On the other hand, it leads to an improved procedure for future wake-vortex measurements.

The computer simulation is based on an improved version of a program by D. C. Burnham*. It includes vortex motion by cross wind and by mutual induction in ground effect. The calculated tangential velocities of both vortices are projected on LOS (line of sight) and added up together with the wind component to get the LOS velocity proportional to the measured Doppler shift. We evaluate the velocities at discrete points along LOS. A weighting-factor proportional to the intensity of the backscattered radiation is attached to each of these points. Together with this weighting factor, the LOS velocities are sorted in velocity bins of given width to simulate the discrete velocity channels of the LDA. The spacing of the points is not constant in order to take care of the greater changes of tangential velocity near the core of each vortex. Varying the elevation angle related with LOS a complete LDA scan is simulated. Changing the parameters of our calculations in order to set up initial conditions as in our measurements we are able to compare measured and computer-simulated data.

One example concerning the comparison of experimental and model results is shown in Figure 1. The strong lines represent the tracks of the port and starboard vortices of a

*Private communication (1985): Feasibility of measuring aircraft wake vortices at 1500-foot altitude.

B-747 aircraft generated at an altitude of 280 m. The numbers indicate the time after generation in s. The distributions of tangential velocities through the vortices after 50 s lifetime are drawn for the model and the experiment. The main difference is caused by the homodyne operation of the LDA system which does not allow a sign determination. By direct comparison, some components of the experimental distribution can be attached to a negative sign (dashed line).

Reasons for additional deviations are specific system properties and the applied measuring procedure.
The first point is the insufficient speed of the data system which reduces the number of individual measurements to 20 per second [2]. The corresponding integration time of 50 ms together with the high speed of the elevation scan smears the elevation range of one measurement over approximately 1°. Therefore, small structures like the areas of highest tangential velocity near the vortex core cannot be resolved.
Another point is the detection and tracking of the vortices. The length of the sensing volume for distances of 200 - 300 m is sufficiently long to get some signal from a vortex. But it is quite difficult to track the moving vortex within the region of highest sensitivity.

The comparison of computed and measured signatures brought some recommendations for future wake-vortex measurements. Two of them are listed below:

- The data system has to be speeded up at least by a factor of 10 to preserve the high angular resolution inherent in Doppler lidar systems.
- The vortices should be automatically tracked by a signal controlled range scan. This can be achieved by installation of a jitter device which overlays the elevation scan by a fast range scan.

References:

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2. Werner, Ch.:
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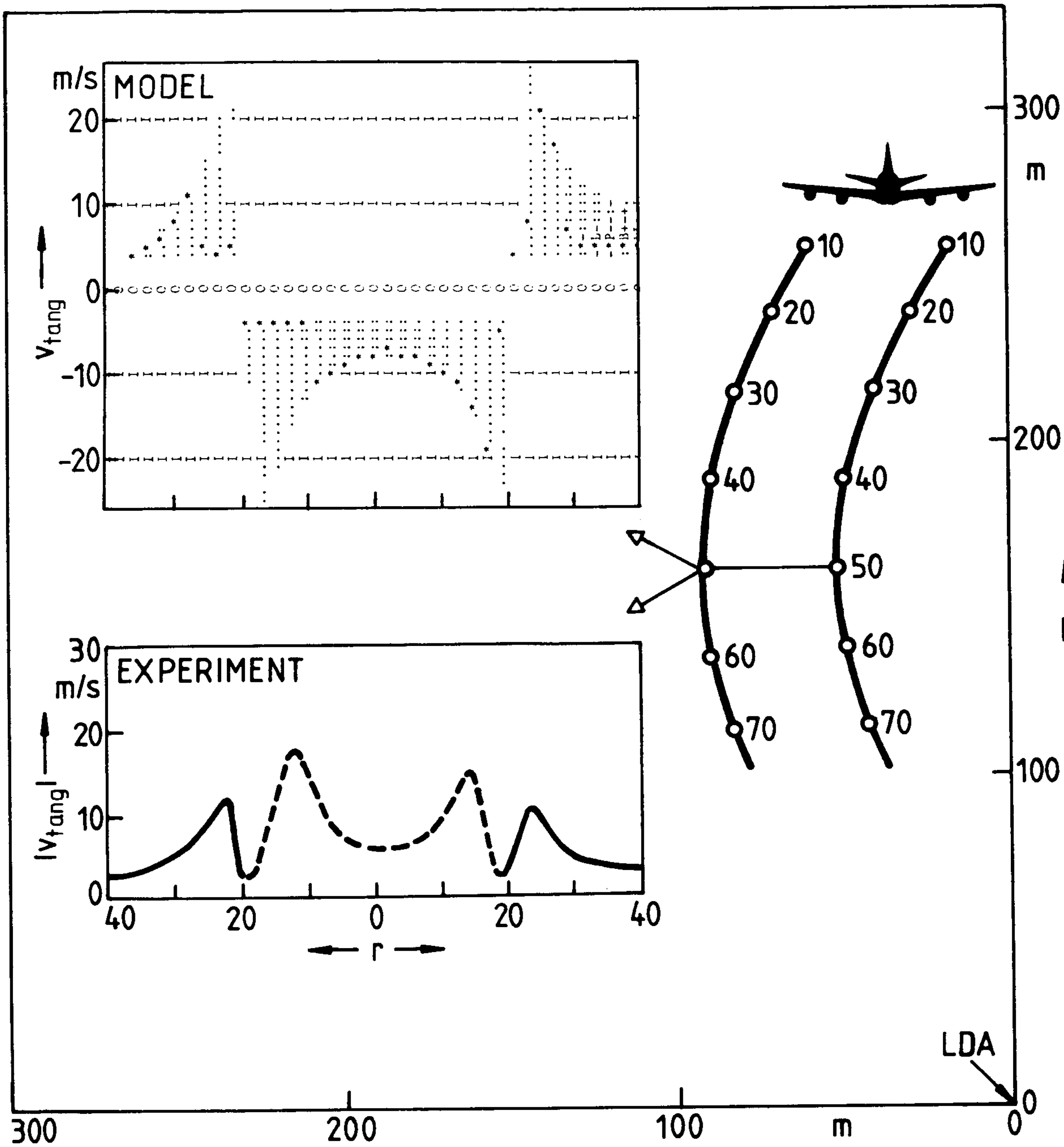

Figure 1. Tracks of both wake vortices generated by a B-747 aircraft passing at 280 m altitude. The theoretical and experimental distributions of tangential velocity 50 s after generation are drawn left. * points of highest signal power.