Electromagnetic radar simulator for wind speed and wake vortices detection

Keywords : Wind radar simulator; Turbulence; Wake vortices detection.

Dmitry Kovalev, Matthieu Duponcheel, Philippe Billuart, Danielle Vanhoenacker-Janvier

Abstract – A new electromagnetic radar simulator has been developed by UCL in the frame of the FP7 UFO project aimed at improving the Wake-Vortex Advisory Systems by the analysis, design and development of innovative technologies for Ultra-Fast Radar and Lidar used as wind and Eddy Dissipation Rate sensors. Experimental trials have taken place at Toulouse airport giving access to concurrent collocated X-band radar data and meteorological data. Preliminary validation of the simulator has been performed against radar and meteorological values of Eddy Dissipation Rate, showing a reasonable agreement. The simulator has also been applied to the detection of wake vortices, in the presence and in the absence of rain.

The UFO FP7 project (Ultra Fast wind sensOrs) [1] was aimed at improving the Wake-Vortex Advisory Systems by the analysis, design and development of innovative technologies for Ultra-Fast Radar and Lidar used as wind and Eddy Dissipation Rate ($\varepsilon^{1/3}$) sensors. These sensors are used for Wake-Vortex hazards mitigation but also for wind sensing and more specifically cross-wind, air turbulence and wind-shear detection on runway for increasing the aviation safety and reducing the safety margin of wake vortex separation between aircrafts during landing and take-off. Experimental trials have taken place at Toulouse and Munich airports.

In the frame of the project, UCL has developed a radar electromagnetic simulator for RCS (radar cross-section), wind and EDR ($\varepsilon^{1/3}$) retrieval, in clear air and in the presence of rain. The simulator is based on refractive index calculated from Large Eddy Simulations (LES) of the turbulent atmosphere in the boundary layer, for selected values of $\varepsilon^{1/3}$ representing various turbulence intensity, and Brunt-VaÃŕsala frequency (N) representing stratification levels. The refractivity is then used for the calculation of the radar cross-section of the turbulences as well as the power received by the radar and the Doppler spectrum.

Using the same X-band radar for the detection of the wake vortices and wind necessitates a careful analysis of the signal received by the radar in clear air due to its low value. The feasibility of using radar and Lidar for the detection of wake vortices and the determination of Eddy Dissipation Rate has been shown experimentally [2].

The Large Eddy Simulation software (LES) used in the UFO project provides realistic velocity, pressure, temperature and humidity fields to the electromagnetic simulator in order to simulate time series of the radar signal. It has been developed by De Visscher and Winckelmans [3] for the study of the effect of turbulence on wake vortices. It has been extended to take into account the humidity transport and the presence of raindrops.

The electromagnetic field emitted by the radar is backscattered by irregularities of the atmosphere, more specifically eddies of the turbulent boundary layer. The Bragg scattering indicates that the radar is sensible to variations of the refractive index of the order of magnitude of half the radar wavelength. The model developed by UCL for the calculation of the backscattering of wake vortices has been extended to be applied to the wind intensity and direction detection.

The turbulent kinetic energy is estimated from the broadening of the Doppler spectrum and $\varepsilon^{1/3}$ is inferred from the turbulent kinetic energy. Various extraction methods have been compared during the project. Fig. 1 shows a comparison between the simulator, the Meteo-France data and the LATMOS CURIE radar data:

- the green dots represent $\varepsilon^{1/3}$ measured by LATMOS CURIE radar in ordinate and measured by Meteo-France in abscissa.
- the red and black + and x are the mean and mean ± standard deviation for the two "packets" of points.
- the red dots represent the values used as input for the LES simulations.
- the blue circles represent the simulated $\varepsilon^{1/3}$ extracted from the Doppler spectrum calculated with the time series simulated using LES at 1s, 30s and 60s of the LES simulation.

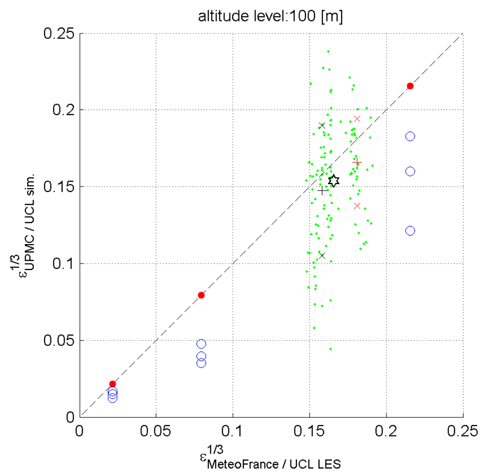

Figure 1: Scatterplot of $\varepsilon^{1/3}$ measured by the LATMOS CURIE radar (ordinate) and issued from Meteo-France High Resolution Weather Forecast Model (abscissa) compared with the simulated $\varepsilon^{1/3}$ (blue circles) on April 10 2014, 9h-16h30.

The underestimation of the $\varepsilon^{1/3}$ calculated by the simulator is further investigated.

For the first time an electromagnetic simulator based on LES simulation of turbulent atmosphere has been tested against radar measurements and meteorological data issued from High Resolution Weather Forecast Model. The next step will be the application of the simulator to wake vortices detection and the inclusion of raindrops.

References

[1] http://www.ufo-wind-sensors.eu/home

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