# P10.2 WIND TURBINE CLUTTER MITTIGATION FOR WEATHER RADAR BY MEANS OF TELEMETRY

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**Abstract**: Wind Turbine Clutter (WTC) has been a problem to weather radar. It features time-varying Doppler spectra and very high reflectivity. These characteristics are similar to storm signatures making them difficult to separate. Radar signature characterization is the basic approach to mitigating WTC from radar observation; a scatterometer is built for such a purpose. As will be proved by the comparison between laboratory and field measurements in this paper, the scatterometer provides very good emulation to radar measurements of wind turbines. With better understanding of wind turbine radar signatures, it is possible to build up a parametric model, which will be combined with telemetric information from sensors on wind turbines to mitigate the WTC in an adaptive way.

Index terms- Wind Turbine Clutter, Radar signature, Scatterometer, Telemetry

## 1. Introduction

With the government's support of green energy, wind energy has thrived in the past few years. As more wind farms are built across the country, their impact on weather radar observations has been studied extensively: Burgess(2008), Vogt(2007). The negative effect of wind turbines on weather radar observations is called Wind Turbine Clutter (WTC). It will affect weather radar signal processing algorithms and decision making in many ways (Burgess, 2007): mis-identification of precipitation echoes, false estimates of precipitation, false mesocyclone signatures, incorrect storm cell identification, and incorrect VWP wind estimates. It is therefore very important to study the radar signature of wind turbines so that better solutions can be found to remove WTC from weather radar observations.

Unlike ground clutter, which is essentially stationary from pulse to pulse, WTC constantly changes with time while the turbines are in motion. Therefore, the Gaussian Model Adaptive Processing (GMAP) method (Siggia and Passarelli, 2004) which is widely used in weather radar to mitigate ground clutter will not be effective. Some methods (Isom, 2007A; Butler, 2003; Palmer, 2008) have also been proposed for removing WTC from radar observation. However, due to the lack of understanding of radar signatures of wind turbines, these methods sometimes fail to preserve weather information while mitigating WTC.

To allow a controlled study of the radar signature of wind turbines, a scatterometer system has been built at the Atmospheric Radar Research Center (ARRC) of the University of Oklahoma. The system includes a wind turbine model and an X-band dual-polarized pulse radar emulator. The model is scaled from a commercial wind turbine and can be precisely controlled in terms of azimuth angle and rotation rate. The system is operated inside an anechoic chamber to avoid interference.

The latest laboratory measurement will be given in this paper and the similarity between laboratory measurements and field measurements will be discussed.

## 2. Scatterometer System

The scatterometer system is a combination of a wind turbine model and a radar emulator:

### 2.1 Wind Turbine Model

The wind turbine model is specifically designed for laboratory measurements. It is scaled with a ratio of about 1:100 to a commercial wind turbine. The model is made of epoxy-fiberglass material with a metallic rod inside as to best approximate the structure of on-site wind turbines that embed a lightning rod within each blade. Fig.1 (a) shows the model set up inside the anechoic chamber.

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Fig. 1 The scaled wind turbine model: (a) inside an anechoic chamber, (b) by a laboratory bench with base and blade controllers connected; connecting cables from the nacelle to controller is within the tower

A computer-controlled step motor is accommodated inside the nacelle of the turbine model. It controls the rotation rate for dynamic measurements and the angular step for static measurements. The whole model rests on a rotor base that changes the azimuth angle with respect to radar line of sight. Fig. 1 (b) shows the turbine model connected to the base controller and the blade controller, which both connect to a computer.

#### 2.2 Radar Emulator

The radar emulator is an indoor radar test bed and is capable of transmitting a narrow pulse-modulated signal with pulse width ranging from 10 to 300 nanoseconds. The center frequency is 10.5 GHz. It has separate horizontal and vertical polarized channels for both transmitting and receiving so that cross-polarized reflection could also be measured.

A simple system block diagram is shown in Fig. 2: The pattern generator sends out a narrow pulse, which turns on/off the switch within the transmitter so that the pulse-modulated signal is generated. The signal is amplified, filtered within the transmitter, and then sent to a dual-polarized antenna through a fast switch that alternates horizontal and vertical modes. Two identical receivers are used for different polarized receiving. The returned signals are then digitized and saved to computer for post processing.



Fig. 2: Block diagram of the radar emulator: the transmitted signal is alternated between H and V channels and received separately, then digitized at a very high sampling frequency for anti-aliasing purpose

## 3. Laboratory Measurement

The wind turbine model is set up so that the plane of the blades is along the radar line of sight and rotating at 40 RPM; the pulse repetition frequency is 390 Hz and data are taken for about 2.5 seconds. The time-varying Doppler spectrum and the time series of returned power are shown in Fig. 3.

The result of field study from Isom (2007B) is also shown in Fig. 4 for comparison.



Fig. 3 Doppler spectrum and time series measured in the laboratory: note the DC component of the Doppler spectrum has been removed; the variance close to DC might have been caused by the center part of the turbine



Fig. 4 Doppler spectrum and time series measured from field study: the data may be collected with interference. The two vertical flashes cannot be from wind turbines; there seems to be two constantly moving targets (probably vehicles) approaching the radar.

It can be seen by comparing Fig. 3 with Fig. 4 that the lab measurement emulates the field measurement well: periodic spectrum flashes are observed in both timevarying Doppler spectra. With the ability to change the pulse repetition time and rotation rate, Doppler spectra aliasing is avoided in the laboratory measurement. Also, because the laboratory measurement is taken inside an anechoic chamber, the noise level is much lower than field data so that more details can be found from time series.

### 4. Conclusions

The laboratory study of radar signature of wind turbines is more controllable than the field study. With full control of both the wind turbine model and radar emulator, it is much easier to collect data in different scenarios to get better understanding of how state parameters of wind turbines affects the measurements. Many wind turbines in the field are able to provide telemetry information, in the form of sensors that measures blade rotation and velocity. It is hoped with enough laboratory study; an adaptive algorithm based on telemetric feedback can be developed to mitigate the WTC effects while preserving useful weather information.

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