DEVELOPMENT OF TURBULENCE DETECTION AND PREDICTION TECHNIQUES WITH WIND PROFILER RADAR FOR AVIATION SAFETY

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ABSTRACT

There are various meteorological phenomena which may cause serious trouble to aircraft operations. Especially, atmospheric turbulence (including wind shear) sometimes brings significant aircraft accidents because it is difficult to detect it by current operational meteorological observations. In the present study, the prototype of the next generation 1.3-GHz wind profiler radar (WPR) that can be observed up to the cruising altitude of the aircraft is developed, and it aims at the establishment of the atmospheric turbulence detection technique by the remote sensing. Two small WPRs (called LQ-7) were combined into one set of a medium size WPR (LQ-13). In addition, the observational data with the WPR is used as verification data to improve the prediction accuracy of atmospheric turbulence. It aims to become the foundation of the aircraft accident prevention.

1. INTRRODUCTION

There are various meteorological phenomena which may cause serious trouble to aircraft operations. Especially, atmospheric turbulence (including wind shear) sometimes brings significant aircraft accidents because it is difficult to detect it by current operational meteorological observations. In 2000-2009, more than half of accidents in large aircrafts were brought by atmospheric turbulence. At present, PIlot weather REPort (PIREP) is a major method for observing atmospheric turbulence, but it is not suitable for monitoring atmospheric turbulence because it cannot continuously observe a specific area or altitude. Therefore, the development of a new observation instrument, which continuously covers wide altitude range, is needed. On the other hand, various forecast techniques for atmospheric turbulence have been developed based on PIREP data, so there is still room for improving its prediction accuracy.

2. PROJECT OUTLINE

The project supported by 'the Program for Promoting Fundamental Transport Technology Research of the Japan Railway Construction, Transport and Technology Agency (JRTT)' started in July 2011. Fig. 1 shows the outline of this project. In this study, the prototype of the next generation wind profiler radar (WPR) that can observe the wind up to the cruising altitude of the

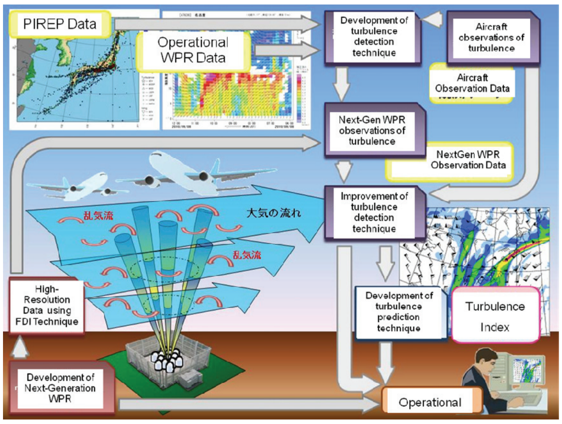

Figure 1. Outline of the project.

aircraft will be developed. This study aims at the establishment of the atmospheric turbulence detection technique by the remote sensing of WPR. In addition, the observational data from WPR will be used as verification data to improve the prediction accuracy of atmospheric turbulence. The goal of this study is becoming the foundation of the aircraft accident prevention through the usage of WPR.

Figure 2. LQ-13 Wind Profiler.

Table 1. Specifications of the LQ-13 system.

Radar system:	Monostatic pulse Doppler radar
Operational frequency:	1357.5 MHz
Antenna:	Active phased array
Aperture:	6.4 m^2
Gain:	32.3 dBi
Beam width:	4 deg.
Beam directions:	zenith, north, south, east, and west
Beam angle:	14 deg. of zenith
Polarization:	Linear
Transmitter:	
Peak power:	5200 W
Average power (max):	1820 W (duty ratio 35%)
Bandwidth:	10 MHz
Pulselength:	0.33, 0.67, 1, 1.33, 2, 4 us
IPP:	50-200 us
Receiver:	
Form:	Double super heterodyne
Bandwidth:	3.6, 1.8, 1.2, 0.9, 0.6, 0.3 MHz
Noise figure:	1.5 dB
Dynamic range:	>60 dB
Data acquisition unit:	
Pulse compression:	(1), 2, 4, 8, 16 bits
Coherent integration:	1-200
FFT points:	64, 128, 256, 512

3. DEVELOPMENT OF NEXT GENERATION WIND PROFILER RADAR (WPR)

A transportable wind profiler (called LQ-7) is an active phased array radar using seven Luneberg lens antennas. It has the center frequency of 1357.5 MHz and the peak output power of 2800 W. Two small LQ-7 wind profilers were combined into one set of a medium size wind profiler (LQ-13). Its overview and specifications are shown in Fig. 2 and Tab. 1. It was renovated to increase a transmitting power and expand an antenna aperture.

4. HIGH RANGE RESOLUTION BY FDI

We use longer pulse to obtain higher altitude data. To compensate the poor range resolution due to longer pulse, Frequency Domain Interferometry (FDI) technique [1] is applied. FDI is a technique to obtain high range resolution using the phase difference among receiving signals for various transmitting frequencies such as five frequencies of -500 kHz, -250 kHz, 0, +250 kHz, +500 kHz relative to 1357.5 MHz. FDI observation results using Capon method could provide us the high resolution data.

5. SUMMARY

We started new project to develop the prototype of the next generation 1.3-GHz WPR that can be observed up to the cruising altitude of the aircraft and to establish the atmospheric turbulence detection technique by the remote sensing. Two small LQ-7 WPRs were combined into one set of a medium size WPR (LQ-13). We will start the observation by LQ-13 soon, and will conduct an experimental application of the frequency domain interferometry technique to LQ-13 and an improvement of the estimation method of turbulence strength. Also, new turbulence prediction techniques will be developed.

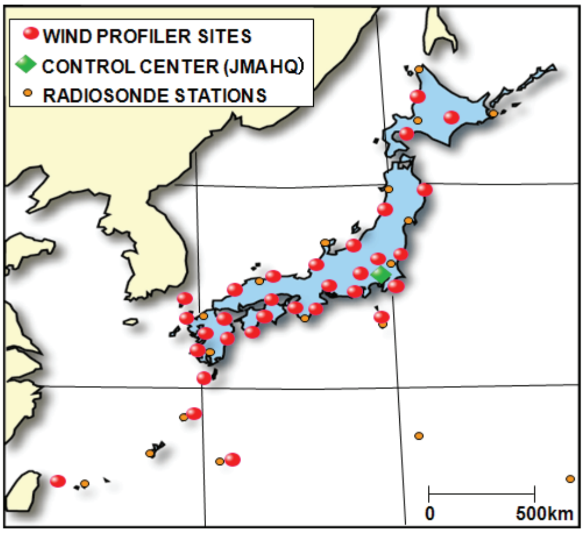

Figure 3. WINDAS: Wind Profiler Network and Data Acquisition System (in 2001)

It is expected that the result achieved by the present study will be built into the WPR network of Japan Meteorological Agency (JMA) for the meteorological observations (Fig. 3) [2]. In addition, it is expected to contribute to a safe service of the aircraft operation through the improvement of the prediction accuracy for atmospheric turbulence.

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