Preliminary design study of airborne phased array weather radar

*Nobuhiro Takahashi[1]

1. Institute for Space-Earth Environmental Research, Nagoya University

The change in the rainfall system such as the intensification of typhoons and the increase of heavy rain is one of the concerned issues about the effects of climate change caused by global warming. Regard to typhoon study, aircraft is the best tool to observe the typhoons that happen remote area. In addition to in-situ observation by aircraft, remote sensing such as radar is an effective means especially for understanding three-dimensional structure of typhoon and its wind field.

For weather radar, the phased array technology is progressing due to recent improvements in solid-state power amplifiers and advances in signal processing technology. The advantage of the phased array radar is electronically scanning the antenna, and this type of radar is also possible to reduce the size of the transmitter by using the solid state power amplifier. Therefore, this radar is suitable for mounting on aircraft.

In this report, preliminary study of airborne phased array weather radar assumed to be installed in jet aircraft (e.g. MRJ, G - II etc.) aiming for typhoon observation. In the study, we first set requirements such as 3-D observation and wind observation in typhoon and constraint conditions as aircraft set-up, then we can examine the feasibility of meeting the requirements.

Considering that target is typhoons, the observation range is several tens of kilometers to several hundreds of kilometers in horizontal direction and near the ground to an altitude of more than ten kilometers in vertical. In the case of typhoons, it is required to observe the wall cloud surrounding the eye. Also, due to the performance of the aircraft, the flight altitude is about 12-13 km at the maximum, sometimes it is necessary to fly avoiding wall clouds reaching dozens of kilometers. Also, since the horizontal wind speed is the maximum in the low altitude near the wall cloud, the aircraft should observe from the high altitude outside the wall cloud. Furthermore, since the size of the antenna is limited due to attachment to the aircraft, it is about several tens of centimeters when it is attached to a pod, for example. Also, assuming that it is about 1 m when attaching it to the fuselage of the aircraft.

Based on these conditions and the current radar technology, the basic specification was determined as follows: frequency is X-band or Ku-band, observation range is 30 km to 60 km, transmission power is about 400 W, and dual polarization is used. Although the radar can measure the velocity in the line of sight direction using the Doppler effect, movement of the aircraft is utilized with the forward and backward beams to measure the wind field. From the demands of 3-D observation and wind speed observation, it is necessary that the scanning angle is at least ±20 degrees.

Considering the efficient observation taking the advantages of phased array technology, it is possible to observe two Doppler velocities with one antenna by switching beams between forward and backward direction. The beam direction is ±30 degrees with respect to the direction orthogonal to the nose direction in this study.

Antenna scanning is also necessary for 3-D observations. For example, when conducting 3-D observation below the altitude of an aircraft, it is necessary to direct the antenna downward by 45 degrees and

perform scanning of ±45 degrees.

One-dimensional phased array observation is conceivable as a method that can be realized by the existing technology. In that case, two radars assign to forward and backward beams are necessarily.

Assuming that the pulse repetition frequency (PRF) of the radar is 2000 to 4000 Hz based on the observation range (30 to 60 km) and the number of pulse integration is 32, 0.9 seconds is required to cover the scanning range of 90 degrees assuming the elevational interval corresponds to the beam width. The observable sensitivity is less 20 dBZ.

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