Development and Observation of the Ku-band Broadband Radar (BBR) Network

Tomoo Ushio¹, Eiichi Yoshikawa², Shigeharu Shimamura¹, and Zen Kawasaki¹,3

¹Osaka University, 2-1, Yamadaoka, Suita, Osaka, Japan, ushio@comm.eng.osaka-u.ac.jp
²Japan Aerospace Exploration Agency, 6-13-1, Osawa, Mitaka, Tokyo, Japan
³Egypt-Japan University of Science and Technology, P.O.Box 179, New Borg El-Arab City, Alexandria, Egypt

(Dated: 15 April 2012)

1. Introduction

We have been proposing and developing a tightly spaced weather radar network (McLaughlin et al., 2009; Junyent and Chandrasekar, 2009; Junyent et al., 2010; Maki et al., 2008) consisting of the Ku-band broadband radar (Ku-BBR) (Mega et al., 2007; Yoshikawa et al., 2010) to rapidly and accurately detect hazardous weather phenomena such as localized scattered thunderstorms, tornadoes, and downbursts. The Ku-BBR is a short-range (from 50 m up to 15 or 20 km) pulse-Doppler radar with remarkably high resolution. Range and temporal resolution are several meters and 1 min per 1 volume scan (30 elevation angles), respectively, achieved by fast-scanning system with pulse compression. A networked observation with Ku-BBRs covers a wide area and efficiently observes the troposphere from a low altitude (several tens of meters) almost without impact of earth’s curvature. Even in urban area with a lot of tall buildings or in rugged mountainous area, the BBR network is useful for detection in lower altitudes. In addition, due to radar network installation with a baseline length comparable with the maximum range, a weather phenomenon in the overlapped areas is multi-directionally and simultaneously observed by several BBRs. In this area, observation with higher quality could be achieved by, for example, precipitation attenuation correction with multi-directional retrieval (Chandra and Lim, 2008), and interferometrically enhanced spatial resolution (Zhang et al., 2005).

In this presentation, the concept, configurations of both hardware and software, and observation results of the Ku-BBR and the Ku-BBR network are described.

2. The Ku-BBR

The BBR transmits and receives wide-band (80 MHz (max)) signals at Ku-band (a center frequency of 15.75 GHz) to use pulse compression, which gives us a high resolution and signal-to-noise ratio (SNR) for volume scatterers (e.g., precipitation particles). The high SNR achieved by pulse compression with a long pulse reduces to integrate coherent or incoherent pulses, and allows us to scan over the entire sky (a volume scan with 30 elevations) within the short time of roughly 1 minute. A bistatic antenna system was applied to reduce a direct coupling level (-70 dB) and to leave a receiver on during transmission for a minimum observational range of 50 m. In order to compensate for strong precipitation attenuation at Ku-band, the BBR is designed as a close-range radar with a maximum range of 15 or 20 km for precipitation with a reflectivity factor above 20 dBZ with a low transmission power of 10 W. These basic elements enabled the BBR to be miniaturized for easy installation. More details of the BBR have been presented by Yoshikawa et al. (2010).

3. The Ku-BBR network

One BBR is installed on the top of a building on the Toyonaka campus at Osaka University (Toyonaka radar, hereafter). The Toyonaka radar can make both single-polarization and dual-polarization observations; the single-polarization observation is described in this paper. Another BBR is installed on a building in the Osaka works of Sumitomo Electric Industries, Ltd. (SEI radar, hereafter). The baseline interval of the two BBRs is about 14.32 km. The SEI radar has many nearby obstacles, and the view of the SEI radar is limited, as shown in observation results shown in the next section. The third BBR is installed on the Nagisa sewage plant, which is 19.00 and 27.35 km apart from the Toyonaka and SEI radars, respectively. The three BBRs cover north Osaka, as shown in Figure 1.
4. Observation results

Examples of observation results during 5 min are shown in Figure 2. Left to right columns of panels indicate observed results of Toyonaka, SEI, and Nagisa radars and Integrated reflectivity of those radars, respectively. In this observation, each BBR scans whole sky with range resolution of 23 m (ideally) with band width of 13 MHz and temporal resolution of about 1 min per volume scan with 30 elevation angles. Interferences among radars are avoided by using different frequency bands, that is, 39 MHz is totally used. While the Toyonaka radar has a good view except for a lightning rod equipped in the north-east direction, the SEI and Nagisa radars have some obstacles (tall buildings) especially for the north-east and south-east directions of the SEI radar, and for the north-west direction of the Nagisa radar. These obstacles reflect much power, and range sidelobes are appeared in most of the range bins for each direction due to pulse compression. Integrated reflectivities are calculated mainly by two processes; 1) the data qualification compares reflectivities of the three radars in nearest points are compared and eliminates outliers, 2) the integration calculates weighting average of the qualified reflectivities, whose weight is dependent on a range between a desired grid point and observed point. As a result, reflectivities wrongly estimated in each radar are eliminated, and fine structures of precipitation are retrieved.

5. Conclusion

The concept, configurations, and preliminary observations of the Ku-BBR network are described. The Ku-BBR is a short-range (from 50 m up to 15 or 20 km) pulse-Doppler radar with remarkably high resolution (range and temporal resolution of several meters and 1 min per volume scan with 30 elevations). Due to these characteristics, the Ku-BBR network efficiently and accurately covers the troposphere and detects small-scale hazardous phenomena. As our future works, accuracy of measurements in the Ku-BBR network and dual-polarization measurements will be evaluated. And, advanced multi-radar retrieval method for the Ku-BBR network, for example, correction for precipitation attenuation, resolution enhancement, and raindrop size distribution retrieval are also planned.

Acknowledgment

This work was supported by grants from Ministry of Education, Science, and Sports and Culture, Japan.

References


Fig. 2 The initial observation results at 14:58, 59, 15:00, 01, and 02 on Oct. 14, 2011. Panels (a-1) through (a-5), panels (b-1) through (b-5), and Panels (c-1) through (c-5) are results from the Toyonaka, SEI, and Nagisa radars, respectively. Panels (d-1) through (d-5) are integrated results from the three radars. In each panel, left-upper, left-lower, and right triangles indicate the Toyonaka, SEI, and Nagisa radars, respectively. The three dashed circles and the solid circle are on ranges of 5, 10, 15, and 20 km from each BBR, respectively.