Development of Active Phased Array Weather Radar

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1 INTRODUCTION.

In recent years, it is increasing weather disasters by severe storm and gust in the regional Japanese cities. Localized severe storm and gust are mostly caused by a cumulonimbus developing to more than 10 km attitude. Weather radar is able to observe the developing situation and the internal structure of a cumulonimbus. In addition, observational data can be utilized in the prediction of precipitation. Weather radar becomes vastly more importance, since it is essential system for observing severe storms and gusts.

Conventional weather radar with parabolic antenna does not have enough time-resolution for observing cumulonimbus, because the life-cycle of a cumulonimbus is about 30 minutes, but conventional weather radar usually requires 5-10 minutes for observing three-dimensional structure of a cumulonimbus. [1] Moreover, since the conventional weather radar has only around 10 to 20 of elevation angle for observation, it is difficult to observe the details of inside cumulonimbus.

In order to achieve both reduction of the time-resolution and increase of the observed elevation angle, we have developed X-band Active Phased Array Weather Radar (PAWR) with Digital Beam Forming (DBF) technology. In this paper we will describe the characteristics of this new-generation weather radar and Active Phased Array Antenna. We will show the measured results of the Antenna, and the results of trial observation actually performed at Osaka urban area in June 2012.

2. SYSTEM OVERVIEW

Figure 1 shows the operational concept image of PAWR. In order to capture the detail of internal structure of clouds in real time, PAWR with 2 x 2 meter antenna will be installed on the roof of the tower buildings in urban areas. The whole PAWR system includes developed antenna is actually covered by a radome.

Figure 2 shows a distinctive of the concept difference between PAWR and conventional weather radar. PAWR is adopted with one-dimensional phased array antenna.

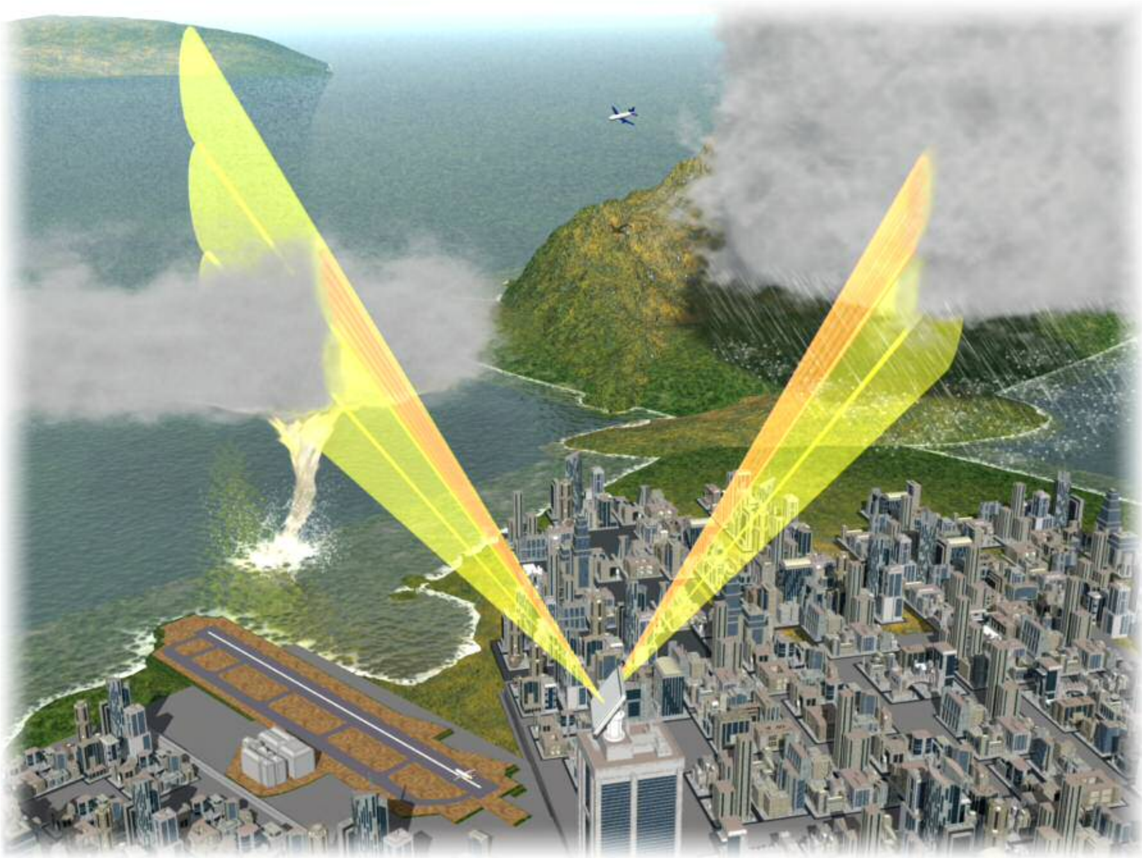
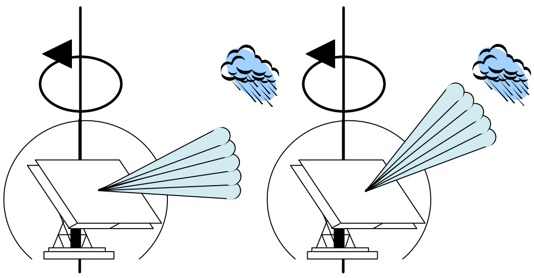
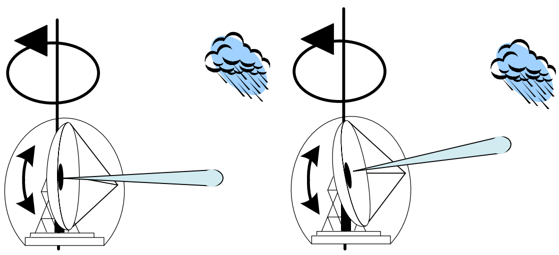


Figure 1 - The Observational Image of Active Phased Array Weather Radar



(a) Active Phased Array Weather Radar.



(b) Conventional Weather Radar.

Figure 2 – Concept of the new-weather radar.

The antenna is embraced with a mechanical drive for azimuth angle and an electronic scan for elevation angle. For elevation angle, the transmitted beam is formed as a fan beam, and the received beams are formed as multi-beam using DBF technology. The main feature of PAWR is able to perform densely 3-D volume scanning without making gaps between each beam.

As specified in Table 1, this system has two observational modes. One is fast observation mode, which has minimum of 10 second interval period with about 20 km observation range. Another is wide observation mode, which has minimum of 30 second interval period with about 60 km observation range.

Table 1 – Main Observational mode and specification.

	Specification	
Maximum Power	Up to 430W	
Frequency	9320 to 9445MHz, 5MHz step	
Beam Width (after DBF)	About 1 deg	
Mode	Fast Observation	Wide Observation
Coverage	20km	60km
Scan Interval	10 seconds	30 seconds
Number of Hit	About 10	About 20
Number of Elevation	About 100	About 100

3. DEVELOPMENT AND EVALUATION OF ACTIVE PHASED ARRAY ANTENNA

We have already developed the active phased array antenna. Figure 3 shows the picture of Antenna. In addition, we have already performed for the antenna pattern evaluation. A developed antenna has 128 of waveguide slotted antennas arranged at 16.5mm pitch. The aperture length of this antenna is 2.2 x 2.1 m.

This antenna has transmitting and receiving units (TxRx Unit), receiving units (Rx Unit), and DBF unit [2] located in the rear side of antenna. Each TxRx unit or Rx Unit has capability of transmitting or receiving up to 8ch. This radar is able to transmit up to 24ch with 3 TxRx Units, and receive up to128ch with 13 Rx Units.

DBF Unit has capability of processing 128ch synchronized A/D conversion and I/Q detection, and it has at least 60dB of dynamic range. The receiving multi beams at 1 deg from 128ch I/Q signals are formed by DBF technology. DBF Unit is capable of simultaneously handling 16 beams at same time.

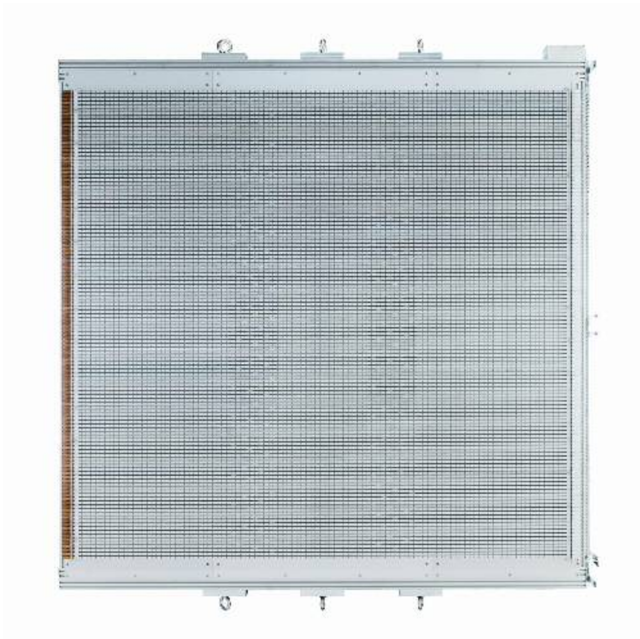
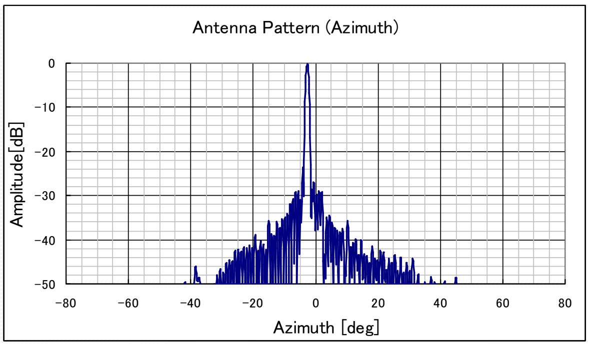
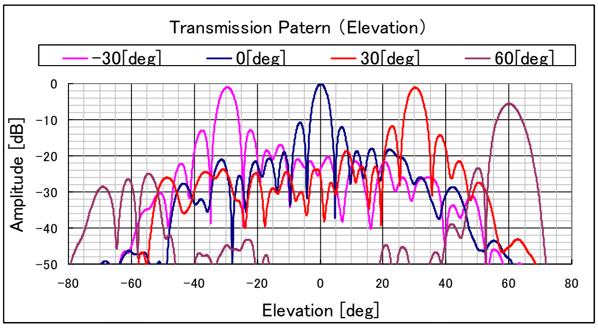


Figure 3 – Developed the active phased array antenna.

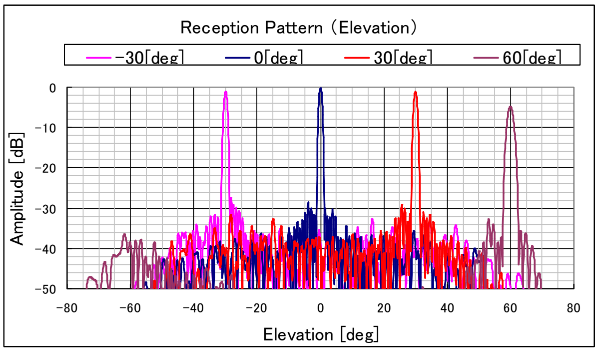
Figure 4 shows antenna pattern of the Active phased array antenna. The transmitting antenna gain is 36dBi or more, and the receiving antenna gain is 42dBi or more. The side lobe level of azimuth angle is -23dB or less. The transmitting side lobe level of elevation angle is -10dB or less, and the receiving side lobe is -23dB or less.



(a) Transmission and Reception Pattern (Azimuth).



(b) Transmission Pattern (Elevation.)



(c) Reception Pattern (Elevation)

Figure 4 – Far-field Antenna Patterns.

The receiving beam width for both azimuth and elevation angle is 1.2 deg or less at elevation 0 deg.

4. DEVELOPMENT OF PAWR AND TRIAL OBSERVATION

Figure 5 shows developed PAWR. Tilt angle of the antenna was set to 30 deg in elevation, transmitted and receiving by time-division radio wave from -30 deg to +60 deg, to observe without a gap from 0 deg to 90 deg in elevation. For the reception pattern of elevation direction, we have achieved to reduce the beam width to less than 1.2 deg at 0 deg elevation. Thus, the spatial resolution is about 500 m at 20 km, 1.3 km at 60 km; also able to observe all of the observation space and output 3D data such as radar reflectivity factor (Z) and Doppler velocity (V) within minimum of 10-second intervals.

Developed system is currently installed on the roof of Osaka Univ. building and is under trial observations. Figure 8 shows a three-dimensional image of the trial observations, which shows rainfall associated with typhoon number 4 in 2012. The precipitation area in the southern part of Osaka is an illustration of a vertical cross-section (color). Currently, based on the observation data, on-going evaluation of the radar system is performed.

Active Phased Array Antenna

Left: Radar Processor

Right: Radar Controller

PAWR installed in Osaka Univ.

Figure 5 – Developed Active Phased Array Weather Radar (PAWR)

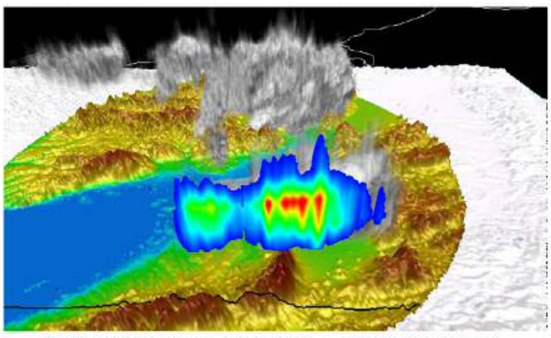


Figure 6 – Trial Observation Data

4. FUTURE WORK

We have developed active phased array weather radar and performed trial observation in the Osaka area. Trial observation proved that three-dimensional observation within minimum period of 10 seconds is feasible. In future work, we will evaluate the three-dimensional observation data which rapidly output. Continuing collaboration with Toshiba Corporation, NICT and Osaka Univ., we will work on development of new signal processing techniques which adaptively forms antenna pattern, data archiving and analysis of so-called "big data" and three-dimensional visualization.

5. REFERENCES

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[2] Y. Shiraishi, R. Suzuki, M. Tanabe, T. Kumamoto, and Y. Masuda, "An X-Band Transmitting and Receiving Power Amplifier Unit using GaN HEMTs for Active Phased Array Antennas," IEICE Technical Report, SANE2010-157, Jan., 2011.

8. ACKNOWLEDGMENTS

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