Development of Multi-Palamer Phased-Array Weather Radar (MP-PAWR)

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1. Introduction

Recently, we see increasing demands for prediction techniques aimed at a growing number of sporadic, localized weather disasters such as heavy rainfalls and tornados. Localized heavy rainfalls are caused by rapid development of cumulonimbus clouds. Cumulonimbus clouds develop in the vertical direction with its lifecycle being just 30 to 60 minutes, bringing heavy rainfalls of more than 100 mm/h within a narrow area. In order to predict heavy rainfalls, it is important to observe potential rainfall up to 15 km in clouds under development. Corresponding to the demands for prediction, the number of R&D of phased-array weather radar have been quite high for recent years. (Bluestein[2010], Isom [2013], Wu[2014], Hopf[2015])

Our team including Toshiba succeeded in the development of single polarization Phased-Array Weather Radar (PAWR), in 2012, which enabled rapid observation of growing cumulonimbus clouds. As of 2016, there are four of PAWR used in Japan.

Moreover, our team developed dual polarization Phased Array Weather Radar called “MP-PAWR (Multi-Parameter Phased-Array Weather Radar)” in 2018. This radar is STAR (Simultaneous Transmit And Receive) system and has DBF (Digital Beam Forming) function. We started to conduct field tests in July of 2018 and have accumulated high quality data of 3 dimensional and dual-pol. This radar will be used for the 2020 Tokyo Olympics with the support from the government of Japan.

2. MP-PAWR (Multi-Parameter Phased-Array Weather Radar)

Our team developed MP-PAWR funded by the government of Japan, under the framework of SIP (Cross-ministerial Strategic Innovation Promotion Program) and installed it at Saitama University. The antenna system of MP-PAWR shown in Figure 1 is mechanically steered in the azimuth direction, while emitting electronic beams in the elevation direction. These are transmitted as fan beams. On the receiver side, pencil beams are formed with DBF (Digital Beam Forming). We chose GPGPU for DBF calculation in real time, because DBF function needs huge computing capacity.

It is important to attain compactness and low-cost, at the same time securing necessary performance underlying dual-polarization observation. Therefore, we adopted patch antenna and RF-CMOS. Antenna elements are important as they directly affect the characteristics of polarization and beam scanning and we adopted polarized shared-aperture slot-coupled patch antennas. Various types of composition are possible depending on how power feeding and the displacement of slots are done. We chose the best layout in a way that both cross polarization suppression in elevation and H/V port isolation are achieved over 35dB in horizontal direction and over 30dB in every direction. And we developed designated RF-CMOS chips only for weather observation.

3. Observed data by MP-PAWR

Since 2018, our team is observing precipitation data by MP-PAWR. Observation range of research mode is
60km radius and time interval is 30 seconds. In this mode, the radar can observe complete 3 dimensional dual-pol data, from 0 to 90 degree in elevation, from 0 to 360 in azimuth, with every 1 degree. Observation range of operational mode is 80km radius and time interval is 60 seconds, observation angle of this mode is from 0 to 60 degree in elevation.
The quality of dual-pol moment data seems to be good and the radar can effectively suppress ground clutter by MTI. We can see structure of cumulonimbus cloud as 3 dimensional movies and particle identification by using dual-pol data clearly visualizes melting layers.

4. Conclusion
With a growing number of world disasters caused by localized heavy rainfall as background, we developed MP-PAWR as one of the dual polarization phased-array weather radars. This radar has many features such as dual polarization capability of STAR, rapid 3D observation with DBF, compact and low-cost in comparison of military or defense phased-array radars with designated RF-CMOS chips, real time calculation with GPGPU and low range side-lobe with NLFM (Non-liner Frequency Modulation) in pulse compression. This radar is accumulating high quality data and evaluating system performance for actual operation usages.

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REFERENCES:


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