Development of Dual-Polarization Phased-Array Weather Radar

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Introduction

An increasing number of disasters caused by extreme weathers such as localized heavy rainfalls and tornados are taking place all over the world. One main cause is rapid growth of cumulonimbus clouds. Generally, lifecycle of a cumulonimbus cloud is about 30 minutes. Weather radars with rapid scanning capability are more than ever required. **Toshiba is developing a dual-polarization phased-array weather radar**.

Table 1. Development Schedule

Years	Phase
2012-2014	1st phase: Development of underlying technology - Funded by Ministry of Internal Affairs and Communication
2014-2018	2nd phase: Development of radar and demonstration - Funded by Cross-ministerial Strategic Innovation Promotion Program - Joint effort with Osaka University, and National Institute of Information and Communications Technology (NICT) - Will develop by early 2017 a dual-pol phased-array weather radar - Will demonstrate its capabilities by 2018

Table 2. Comparison of Radar Performances

Item	X-Band Dual Pol Radar with Parabolic Antenna	Single Pol Phased-Array Radar	Dual Pol Phased-Array Radar
Observation Range	Radius of 60km	Radius of 60km	Radius of 60km
Sensitivity	Less than 1mm/h @ 60km	Less than 1mm/h @ 60km	Less than 1mm/h @ 60km
Temporal Resolution	5 min to 10 min	30 sec to 60 sec	30 sec to 60 sec
Polarization	Dual Polarization	Single Polarization	Dual Polarization
Beam Shape	Pencil Beam for Both Transmission and Reception	Transmission: Fan Beam Reception: Pencil Beam	Transmission: Fan Beam Reception: Pencil Beam
Beam Scanning	Mechanical for Both AZ/EL	AZ: Mechanical EL: Electronic	AZ: Mechanical EL: Electronic
Antenna	Parabolic	Phased-Array	Phased-Array

Requirements for development of dual-pol phased array weather radar:
- compact, low-cost dual-pol antenna with high cross polarization discrimination
- compact, low-cost receiving front-end to reduce cost per channel of system

Radar Cell Design for Compact, Low-Cost System

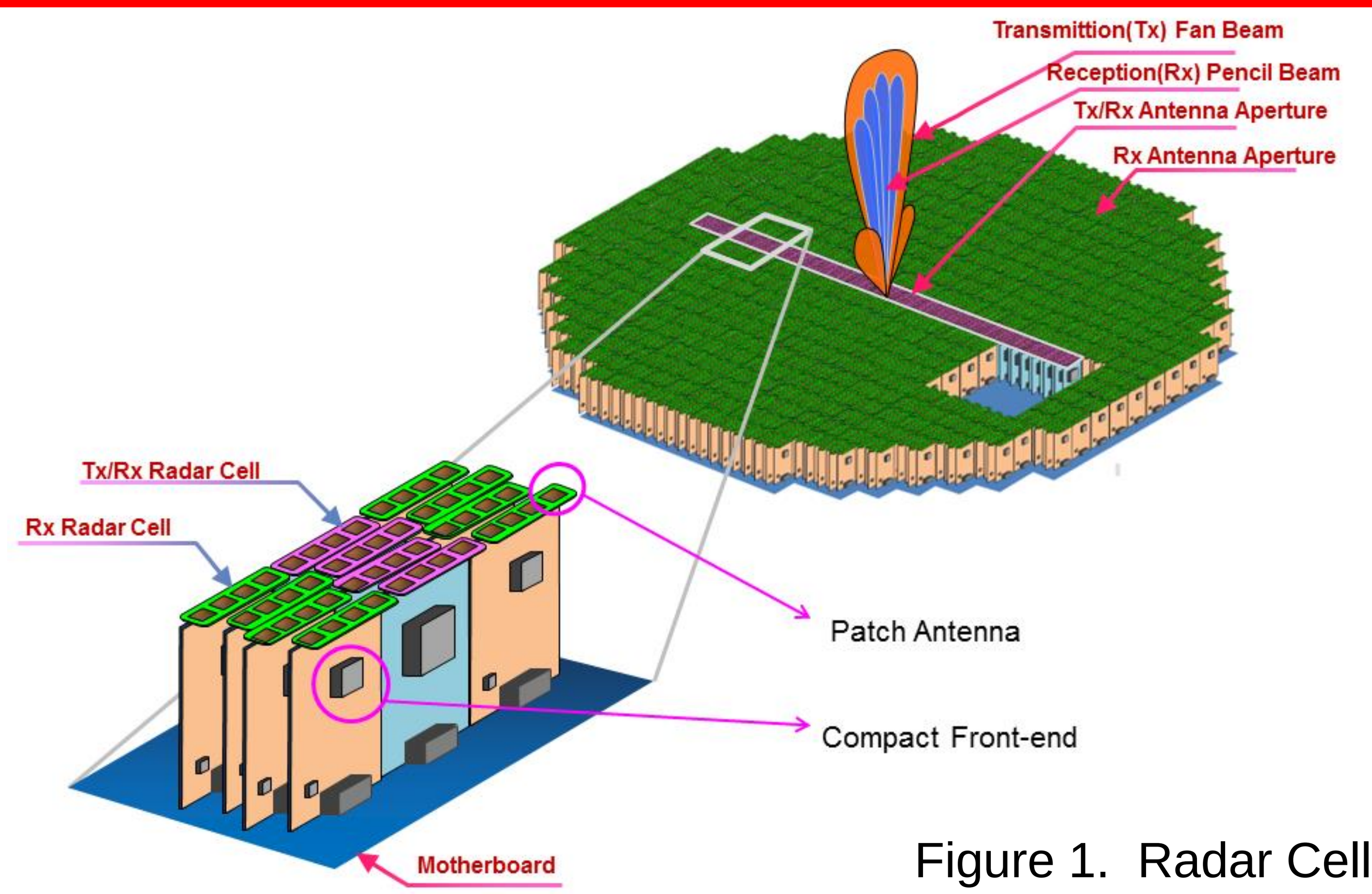

Figure 1. Radar Cell Image

1. Design of Antenna Structure Optimized for 2-Dimensional Array
- Slot coupled patch antennas are aligned on a plane.
- Polarizations in the horizontal and vertical directions share one antenna element.
- Layout of polarization slots / feeder circuits was determined to attain high H/V port isolation.

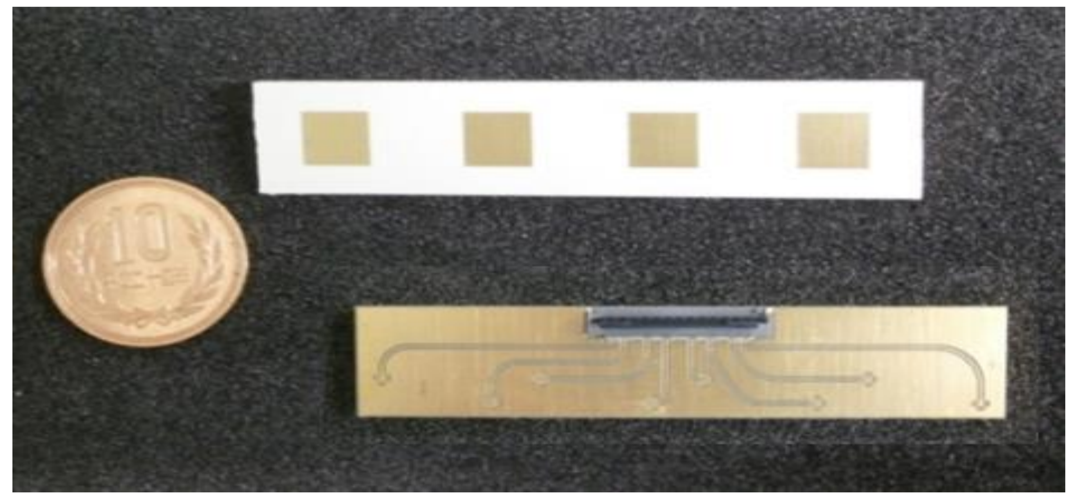

Figure 2.
Patch antenna : 4x1 element prototype
(69.82mm x 15mm for X-Band)

2. One Chip Solution for RF Receiving Front-End
- Phased-array radar transmits fan beams, receives pencil beams.
- About 90% of array elements are only for reception.
  Receiving front-ends were previously realized as discreet elements, which makes the system bigger and costly.
- We succeeded in high integration of basic functions, such as frequency mixing and filtering on a single IC Chip.
  With 180nm process of CMOS technology, the dual-pol RF front-end is realized on a 3mm x 3mm bare chip size for X-band.

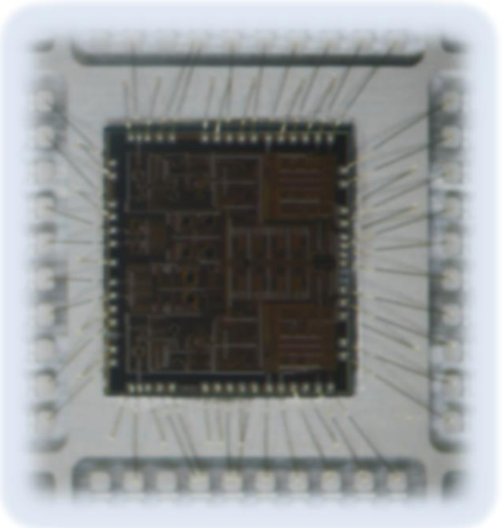

Figure 3. bare chip
(3mm x 3mm)

Preliminary Results

Prototype : made of patch antennas, an RF receiving front-end IC, and a digital back-end.

1. High XPD (Cross Polarization Discrimination): more than 30dB near the front direction(+/- 30deg)

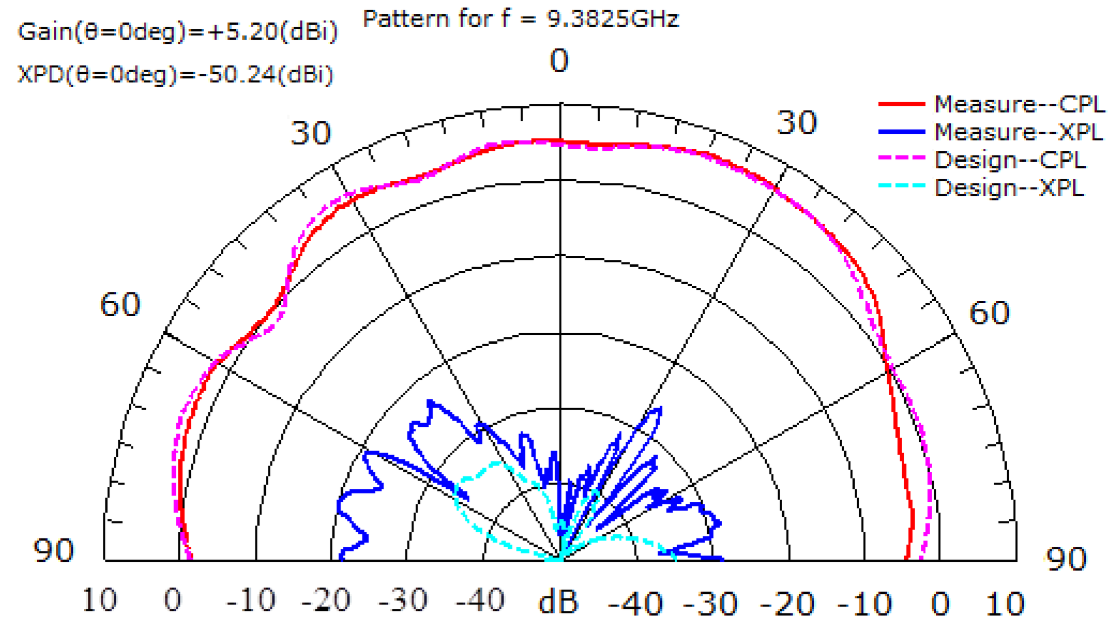

Figure 4. Antenna Radiation Pattern

2. Improved Gain Characteristics of RF Receiving Front-End

Red Line (1st Prototype) : there was shortage of gain and shifted frequency of peak gain, due to stray capacity of local lines and inaccurate modeling of power supply inductor model, respectively.

Blue Line (2nd Prototype) : improved gain of more than 20dB and corrected peak gain frequency were obtained by modified layout and modeling design.

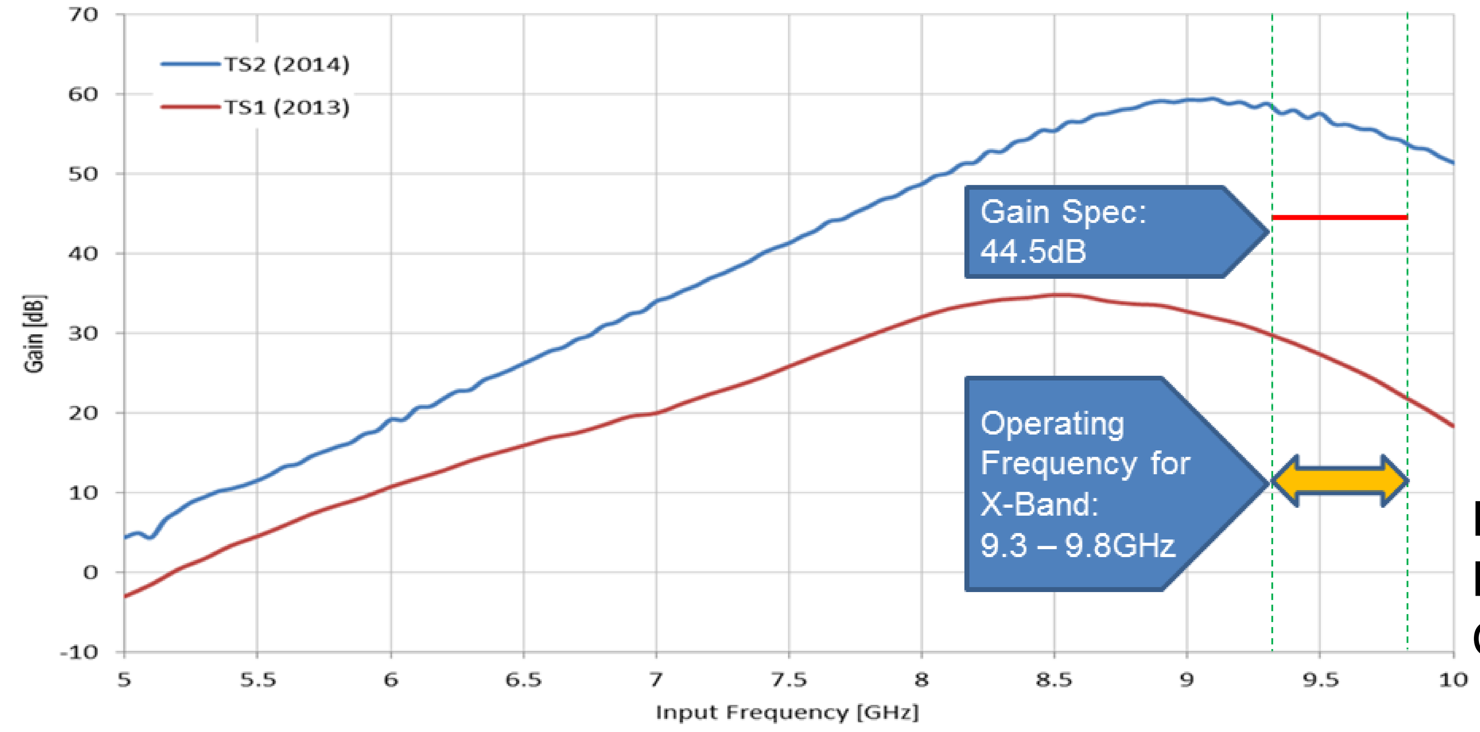

Figure 5. Receiver Gain Characteristics

Conclusion

We succeeded in developing a compact, low-cost radar cell without losing performance required for dual-polarization phased-array weather radar.

Based on the preliminary results of the radar cell we will be able to develop a dual-polarization phased-array weather radar.