[EN-I-080] 90GHz-band FOD detection Radar system for Runway Surveillance

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Abstract: This paper reports a feasibility demonstration and evaluation of a Foreign Object of Debris (FOD) detection radar system using Radio over Fiber (RoF) Technologies. Demand for FOD detection system for airport runway is increasing due to the rapid growth of air traffic all over the world. Airport operators must maintain runway surface safe and clean while various kinds of airplane frequently takeoff and landing. Owing to very short wavelength and wide frequency band allocation, 92-100GHz-band Frequency modulated continuous wave (FMCW) radar with RoF technology is a good candidate for FOD detection system for runway surveillance. During our national R&D project for 90GHz-band FMCW radar, we have installed feasibility demonstration radar system with four radar units beside runway and one control unit near the control tower of Narita International Airport. The precision FMCW signal generated in the control unit can be shared and transmitted through optical fiber to each radar unit. The optical FMCW signal can be converted and amplified in the radar units. Mechanical rotating antenna transmit and receive the FMCW signal to get a PPI scope. On Narita international airport runway B, we have demonstrated sample FOD (The radar cross section of -20dBsm, one inch metallic cylinder, etc.) detection from about 450m distance range.

Keywords: Surveillance, FOD Detection, Millimeter wave RADAR, Radio over Fiber

1. INTRODUCTION

International Air Transport Association (IATA) estimates the number of travelers by air will increase at an annual rate of 3.8% from 3.3 billion in 2014 and reach to 7 billion in 2034. Along with this, the number of aircraft is also increasing and the density of takeoff and landing per hour tends to increase. In fact, takeoff and landing at Narita International Airport and Haneda International Airport are conducted every few minutes.

On the other hand, the US Federal Aviation Administration (FAA) report said the annual direct cost related to Foreign Object of Debris (FOD) removal is estimated 120 billion JPY worldwide and the indirect cost such as the damage from flight delay and the jet fuel loss during holding is estimated 1,300 billion JPY. The demand including these economic aspects to detect the FOD on the runway electronically is increasing.

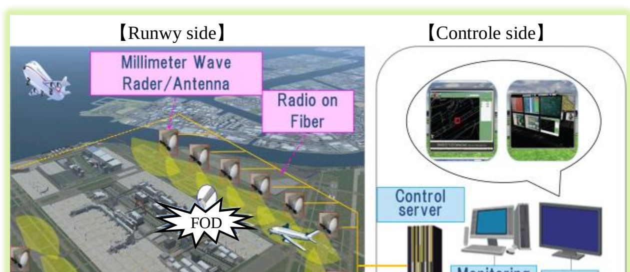

Fig. 1. The concept of the FOD detection radar system for runways.

2. SYSTEM OVERVIEW

Fig.1 shows the concept of the FOD detection radar system for runways. To balance the radar performance improvement and the system cost reduction, the high-accuracy and high-stability Frequency modulated continuous wave (FMCW) radar signal is generated and converted to optical signal at the control side (right side of Fig.1), and transmitted to the multiple radar units deployed aside the runway (left side of Fig.1)through the low loss optical fiber.

Fig.2 shows the location of the four radar units installed beside the Narita International Airport Runway B.

We essentially considered that the cost reduction is one of the important development requirements. We studied the layout plan including the location with the existing facilities to share the power supply facilities and optical fiber equipment with the existing airport equipment.

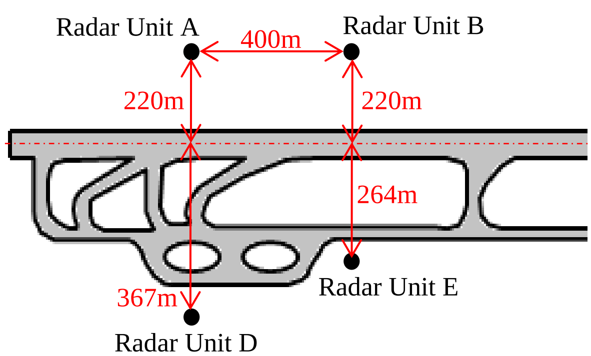

Fig. 2. Location of the four radar units installed beside the Narita International Airport Runway B.

Fig.3 shows the installed radar unit beside the Narita International Airport Runway B. The unit is placed top of the steel pole.

Fig. 3. Image of Radar unit.

Fig.4 shows the configuration of radar RF unit of the RoF (Radio over Fiber) connected radar deployed aside runway. To improve the receiving sensitivity, the Bi-Static type configuration is adopted. The FMCW signal transmitted from the control side with 30 GHz is converted into electrical signal by PD (Photo Detector) and is amplified and radiated to the space after multiplication by three. The radiated radar signal from Tx unit is reflected by the target object and received by the Rx unit.

The Rx unit mixes the received signal with the transmission signal to generate the intermediate frequency (IF) signal which includes the information of the target object location.

The IF signal is converted to digital signal by the runway side A/D converter and returned to the control side.

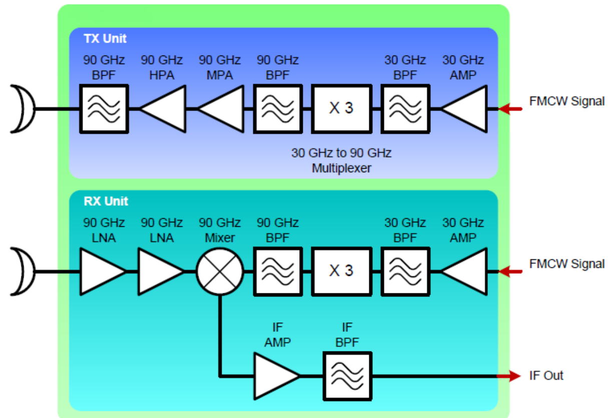

Fig. 4. Configuration of a radar RF unit.

Fig.5 shows the overall configuration of the radar system with the control side equipment. The equipment beside the runway including the radar unit and control side equipment are connected via the existing optical fiber network. The control side equipment generates the optical FMCW signal from the laser source and electrical FMCW signal, and amplifies and distributes it. Then the optical signal is transmitted to the each radar unit via the optical fiber. The control side equipment also consolidates IF signal from each radar radio unit, processes the FFT (Fast Fourier Transform), and displays and stores the FOD information integrally.

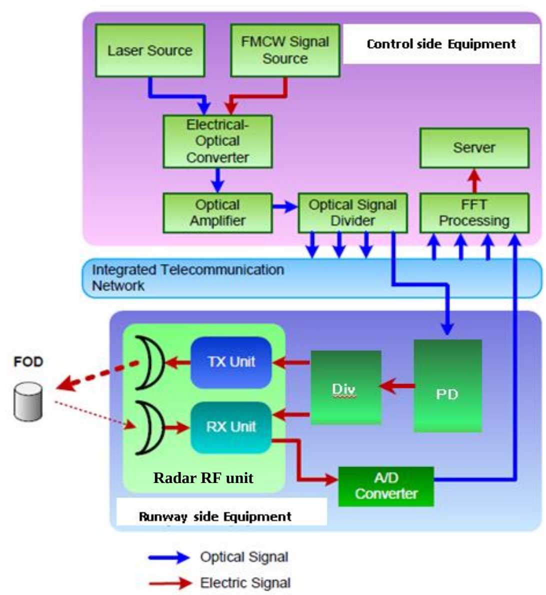

Fig. 5. Overall configuration of the radar system.

3. DETECTING PERFORMANCE

We have installed feasibility demonstration radar system with four antenna equipment beside runway B and one control unit near the control tower of Narita International Airport. Fig.6,7,8,9 shows the radar PPI (Plan Position Indicator) scope obtained from the four radar units.

The reflection from some structures around the runway and the grass area can be measured clearly. A distance of up to 500m can be measured per a radar unit. By installing multiple radar units in this way, it is possible to easily expand the detection area.

These multiple detection results are sent simultaneously to the control side and can be managed all together.

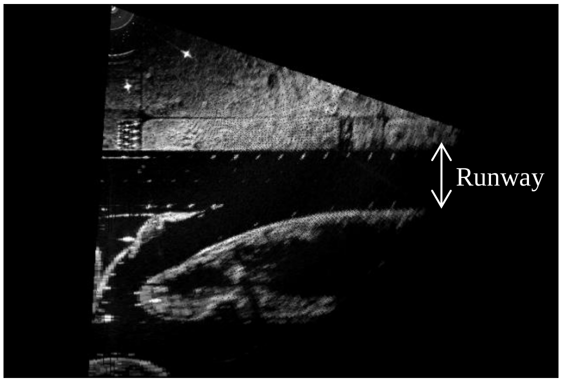

Fig. 6. Measured PPI scope of Radar Unit A.

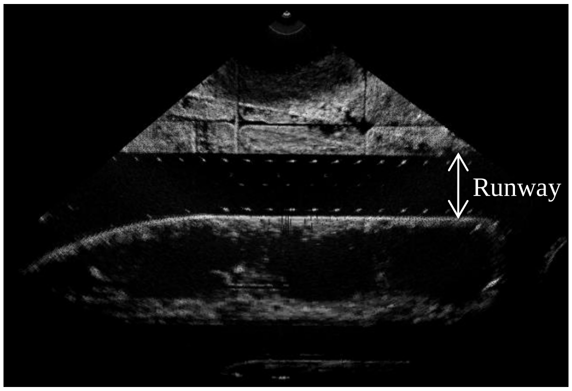

Fig. 7. Measured PPI scope of Radar Unit B.

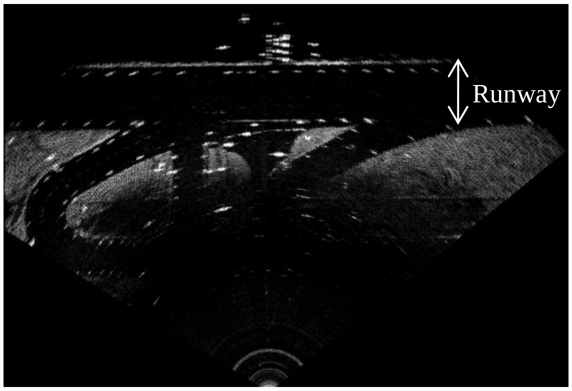

Fig. 8. Measured PPI scope of Radar Unit D.

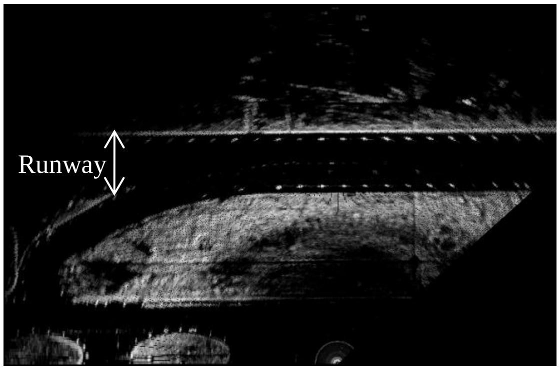

Fig. 9. Measured PPI scope of Radar Unit E.

Fig.10 shows the measured PPI scope of radar unit E when there are various objects on the runway in the middle of the night, after completing the airport operation.

The radar cross section (RCS) of 30dBsm and 5dBsm reflectors and RCS of 0dBsm and -20dBsm metallic cylinders are placed on the runway. Furthermore, some people are standing on the runway at same time. From small reflection to large reflection, we can observe simultaneously.

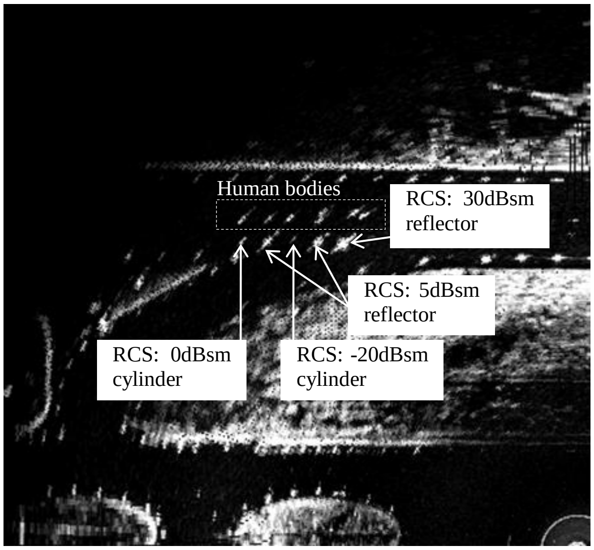

Fig.10. Measured PPI scope of radar unit E when there are various objects on the runway.

This system was optimized to detect a metal object of RCS: -20dBsm placed away from 500 m. Fig.11 shows the detecting result of the -20dBsm metallic cylinder object on Narita International Airport Runway B in the middle of the night, after completing the airport operation. Fig.11 is the result of moving the position of the cylinder with respect to the distance direction of the radar unit.

The spectrum around 426m is due to reflection from the runway lights, therefore it does not move.

We found out that the target -20dBsm metallic cylinder away from 442 m were detected with S/N (signal to noise ratio) of about over 15 dB against the noise level.

We were not able to get the data of 500m distance because of the installation limit on the runway, but we can estimate that it is detectable enough from the radar equation. Even if the distance increases by about 60 m, S/N deterioration is only 2dB.

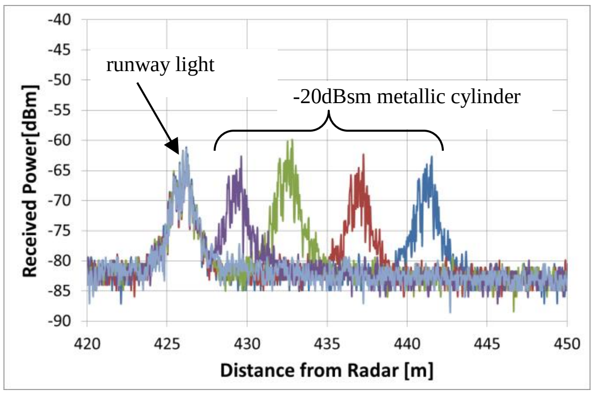

Fig. 11. Measured spectrum of the -20dBsm metallic cylinder.

4. CONCLUSIONS

During our R&D project for 90GHz-band FMCW radar, we have installed feasibility demonstration radar system with four radar units beside runway and one control unit near the control tower of Narita International Airport runway B. The four radar units are operated from one control side equipment, and each detection results can be acquired at once. We have demonstrated sample FOD (RCS:-20dBsm metallic cylinder) detection from about 450m distance range.

5. ACKNOWLEDGMENTS

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