Fundamental Field Evaluations of Radio-over-Fiber Connected 96 GHz Millimeter-Wave Radar for Airport Surface Foreign Object Debris Detection

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***Abstract*—Debris on the airport surface such as on runways may cause severe damage to aircraft. To detect these obstacles, we have been developing a radio-over-fiber (RoF) connected foreign object debris detection 96 GHz millimeter-wave radar system. This paper discusses the fundamental field evaluations of the developed RoF based radar system at Sendai Airport. The radar transmission signal is delivered to the radar antenna unit using optical fibers more than 1,000 m in length. The measurement results confirm the radar target detection on the runway.**

I. Introduction

EVEN if the debris on an airport surface is of small volume and light weight, these objects may cause damage to aircraft. For example, a thin metallic strip caused fatal damage to an aircraft [1]. To detect these small debris, the foreign object debris (FOD) detection systems have been developed based on various technologies.

The millimeter-wave radar systems are suitable devices for the FOD detection systems from its high-sensitivity, high-range resolution and weather robustness. We have been developing a FOD detection radar system utilizing W-band [2]. The developed radar system has a radar signal generation unit and radar antenna units. To reduce the number of the high-cost complicated radar signal generator and processor, these units are connected by optical fibers based on Radio-over-Fiber (RoF) technology. In this paper, the field evaluation of the test bed millimeter-wave radar system using buried optical fibers at an actual airport is discussed. In addition, the generations and the transmission of the radar signal are described.

II. Field Evaluation

The developed RoF connected FOD detection millimeter-wave radar system employs the frequency modulated continuous wave (FMCW) radar method and utilizes the wide transmission frequency bandwidth of between 92 GHz and 100 GHz. By utilizing the 8 GHz bandwidth signal, the cm-class range resolution can be obtained [3]. Fig. 1 shows the location of the 1,050 m single-mode optical fiber, which is used for the FMCW radar signal transmission at the airport field evaluations. In the experiments, the buried fiber cables connect the radar signal generation unit inside the facility building and the radar antenna unit at the side of the runway.

Fig. 2 shows the block diagram of the FMCW radar signal generation and transmission. The 4 GHz FMCW radar signal is generated by the arbitrary waveform generator. Then, the signal is multiplied by four using the two-stage electrical frequency doubler. As a result, the 16 GHz FMCW radar signals, which is a sixth part of W-band millimeter-wave radar signal, is generated at the signal generation unit inside the facility building.

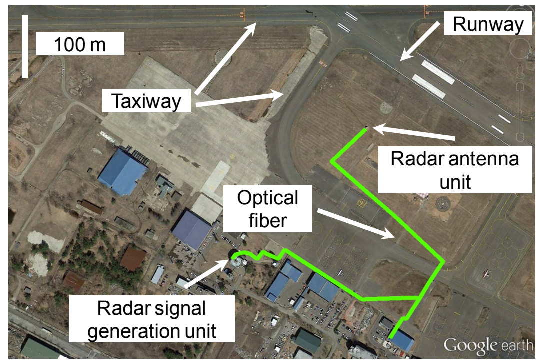

Fig. 1. Location of the 1,050 m single-mode optical fiber cables at Sendai Airport. The buried fiber cables connect the radar signal generation unit inside the facility building and the radar antenna unit at the side of the runway.

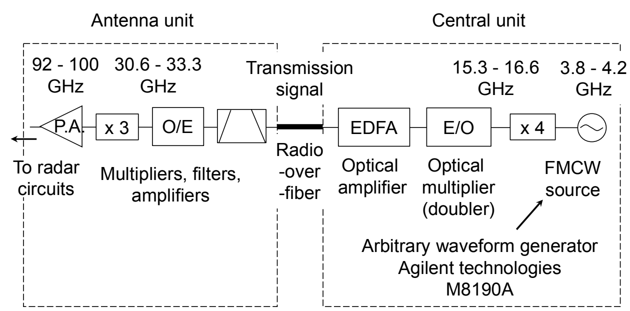

Fig. 2. Block diagram of the frequency modulated continuous wave (FMCW) radar signal generation and transmission. The FMCW radar signal is generated at the central unit. Then, the signal is converted to a higher frequency band using the electrical and optical multipliers.

Then, the electric signal is converted to the optical signal. To improve the long distance RoF transmission characteristics, the optical double sideband suppressed-carrier transmission technique is applied [4]. By using the suppressed- carrier method, the dispersion characteristic of the optical fiber can be negligible. To improve the carrier-to-noise ratio (CNR) of the FMCW radar signal, the erbium-doped fiber amplifier (EDFA) is applied just after electrical to optical (E/O) conversion. The EDFA compensates the loss of the E/O and the optical to electrical (O/E) conversions and maintains the signal CNR, which is almost the same as without the RoF transmission. Then, the optical signal is transmitted to the radar antenna unit at the side of the runway. The optical signal is converted to the elect- rical 32 GHz band FMCW signal. Finally, the W-band FMCW transmission signal is obtained by the 32 GHz band FMCW signal using the frequency tripler.

Fig. 3 shows the overview of the radar antenna unit. As shown in the figure, radar transmission signal is provided by the optical fiber. In addition, the radar is a monostatic construction with a parabolic reflector antenna which is made of the

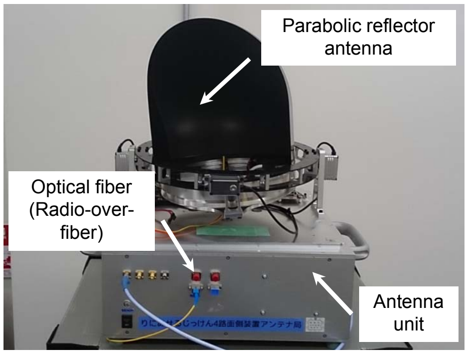

Fig. 3. Overview of the antenna unit is shown. The radar transmitting signal is provided by the optical fiber based on radio-over-fiber technology.

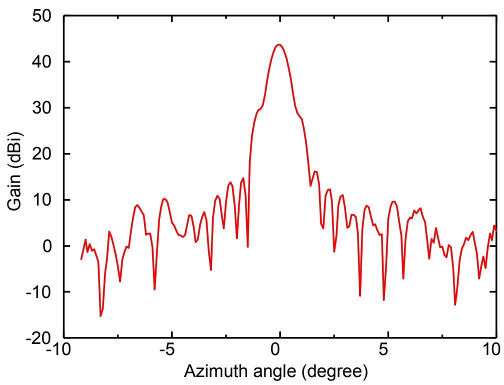

Fig. 4. Azimuth radiation characteristics of the parabolic reflector antenna made of carbon fiber reinforced plastics. The radiation pattern at 96 GHz is shown.

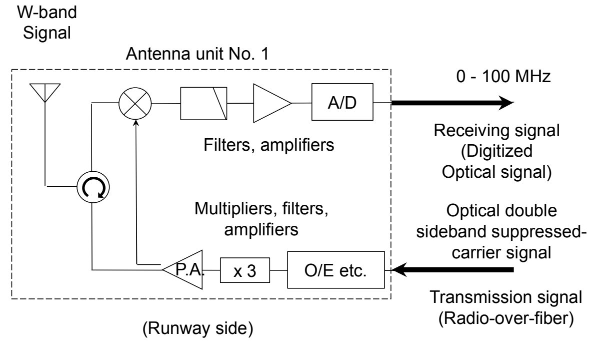

Fig. 5. Block diagram of the antenna unit which includes the W-band radar front-end circuits. By using the distributed radar construction, the radar signal generation circuits and the radar signal processing circuits are not included in the antenna unit.

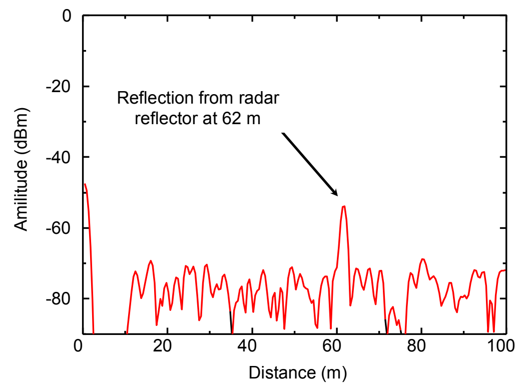

Fig. 6. The measured 1-dimensional radar range spectrum at the airport field test. The antenna unit and radar reflector are located at the side of the runway and in the middle of the runway, respectively.

carbon fiber reinforced plastics (CFRP). To obtain the reflection from the FOD on the airport surface, the antenna mechanically rotates for the azimuth plane. The azimuth radiation characteristics of the CFRP parabolic reflector antenna at 96 GHz are shown in Fig. 4. The antenna gain and the half-power beam width are almost 44 dBi and 0.7 degrees, respectively. The antenna has typical pencil beam characteristics to obtain maximum detection range. Fig. 5 shows the block diagram of the antenna unit which includes the W-band radar front-end circuits. By employing the distributed radar architecture, the radar signal generation circuits and the radar signal processing circuits are not required in the antenna unit.

III. Discussions

To confirm the fundamental characteristics of the constructed RoF connected 96 GHz millimeter-wave radar system, the field evaluation was carried out at Sendai Airport. The central unit and the antenna unit are located inside the facility building and at the side of the runway, respectively. In this experiment, one antenna unit is connected to the central unit to evaluate the fundamental operation of the radar system. Fig. 6 shows the measured 1-dimensional radar range spectrum at the field test. The 30 dBsm radar reflector is located in the middle of the runway, which is 62 m away from the radar antenna. The reflection signal is clearly observed at the place of the reflector. The sensitivity of the radar system is required to be improved, however, the field feasibility where the actual buried optical fibers at the airport are utilized, is experimentally confirmed by the measurements.

IV. Conclusions

The fundamental characteristics of the RoF connected 96 GHz millimeter-wave radar system was evaluated at an actual airport. The millimeter-wave radar transmission signal was delivered to the antenna unit through the optical fibers more than 1,000 m in length. In addition, the reflection signal from the target located on the runway was confirmed by the field test.

Acknowledgement

This work was partly supported by “Research and development of fundamental technologies for advanced radio frequency spectrum sharing in mobile communication systems” from the Ministry of Internal Affairs and Communications (MIC) of Japan.

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