

Evaluations of Incident Angle Characteristics Airport Runway Clutter Using the 96 GHz Millimeter-Wave Radar for Foreign Object Debris Detection System

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Foreign object debris (FOD) detection systems at airports are new surveillance systems that support airport safety. These systems automatically detect FOD on airport runways and inform airport operators, thereby preventing accidents (resulting from FOD) and shortening runway closure periods for safety inspections. We developed an FOD detection system based on a 96 GHz millimeter-wave radar sensor (S. Futatsumori et al., 2024 IEEE Conference on Antenna Measurements & Applications, pp.1–3, 2024). To determine the height of the millimeter-wave radar, it is necessary to investigate the range of the optimum incident angle by considering runway clutter characteristics. In this study, the incident angle characteristics of airport runway clutter power are evaluated using radar for the FOD detection system. First, the specifications of the 96 GHz millimeter-wave radar are discussed for airport runway clutter evaluations. Subsequently, a measurement setup at the airport is introduced. Finally, the incident angle characteristics of the runway clutter power at 96 GHz are discussed based on the results.

The 96 GHz millimeter-wave radar has a frequency range of 92–100 GHz. The maximum transmitted signal bandwidth is 8 GHz. A linear triangular frequency-modulated continuous-wave (FMCW) chirp is employed for ranging. The transmission power and antenna gain are 18 dBi and 42 dBi, respectively. The radar is installed on a variable-height measurement platform. The height of the platform varied between 5.0 m and 20.0 m, in steps of 2.5 m. As an airport runway has a cross-sectional gradient, a certain height is required to avoid a blind radar coverage area on the far side of the runway. Fig. 1 (a) shows the experimental setup at Sendai International Airport, with the runway sensor located on the side of the runway. The distance between the radar and the runway center is 150 m. Fig. 1 (b) shows the incident angle dependency of the runway clutter power. The runway clutter power is evaluated at the center, near, and far sides. The incident angle varies between 1.4° and 5.3°. For all the locations, expect the incident angle of 4.3° at the centerline, the runway clutter power increased monotonically as the incident angle increased. However, the slope of the change and maximum and minimum values differed depending on the measurement point. At the near side, the runway clutter is more than -50 dBm even at the lowest incident angle of 1.4°. However, the runway clutter is approximately -70 dBm at the same incident angle. This is mainly owing to the runway cross-sectional gradient, which is steeper on the runway surface closer to the runway centerline. Conversely, the runway surface farther from the radar had a lower slope than that of the runway's centerline. The incident angle characteristics of the clutter power will be used to design the height of the FOD detection millimeter-wave radar sensor.

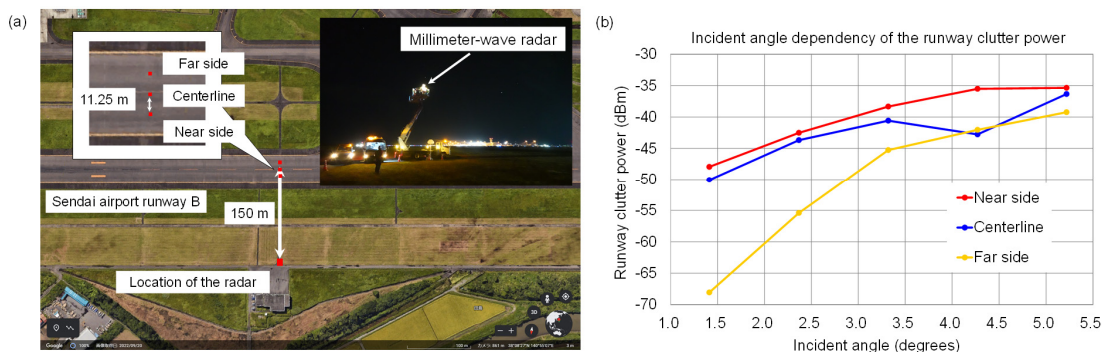


Figure 1. (a) Experimental setup at Sendai International Airport. (b) Examples of the measured incident angle dependency of the runway clutter power.